THE UNIVERSITY OF ALBERTA

A STUDY OF RESIDENTIAL WATER USE IN CALGARY

by

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ABSTRACT

Residential water use in Calgary has been increasing rapidly over the past few years. Residential water users in Calgary have their choice of either a flat rate or a metered rate for their water. Calgary's unique dual rate system allows for an investigation into the effects of the two pricing methods. This thesis is an enquiry into the effects of the various factors, including pricing method that influence household water consumption.

A random sample of flat rate and metered water users was drawn in the fall of 1968 from the billing lists of the Consumer Service Department. Each sampling unit drawn received a mail questionnaire with questions pertaining to family and household characteristics. A personal interview was conducted at all homes not replying to the mail questionnaire in order to check for non-response bias. Additional information on each household was obtained through the Consumer Service and Land Assessment Departments of the City of Calgary.

The results of the analysis pointed out some important findings that should be considered in planning for future residential water use. First, households on a flat rate, ceteris paribus, average substantially greater water use than metered households. Second, the major water-using appliances in the home are washing machines followed by

automatic garbage disposals and dishwashers; while the major water-using fixtures are washbasins and sinks, and toilets. Third, an indication for the need to meter was found in the large variance of water consumption between households in the same socio-economic class. Fourth, seasonal peaking increases faster than average water use as the value of the home and income increases. Fifth, the use of mail questionnaires results in an over-estimation of population characteristics (i.e. biased estimation).

ACKNOWLEDGEMENTS

This study could not have been undertaken without the assistance of many people. I would like to thank Mr. C. Shier, Dr. W. E. Phillips, and Mrs. M. E. Richeson for their contributions to the study. The assistance of the City of Calgary's Water Works Department and Consumer Service Department is also greatly appreciated. I am particularly grateful to Dr. W.M. Schultz who directed the research of this thesis and made so many invaluable suggestions throughout my work.

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INTRODUCTION

The Problem

The growth of urban and suburban centers and the increasing number of water using devices is putting pressure on municipal water supplies to meet the ever increasing demand for water. In order to meet the increasing demands upon water systems, there are four positive alternatives from which the municipality has to choose. The first is to rebuild or expand the present water supply. Second, build an entirely new water system. Third, make better use of the existing water system. Fourth, some combination of the first three alternatives. The third alternative is a good choice for any public water system because it does not create any new costs to the system.

Although municipal water supply is essential for community growth and development, until recently little attention was paid to public water systems when compared to other public utilities. Milliman has suggested three possible factors that help explain this lack of interest in municipal water supply. First, with the exception of treatment of raw water before distribution technology of public water supply has changed little over the years. Second, the costs of urban water have been very low in relation to its worth to its different uses. Finally, the area of urban water supply has seldom been the subject of partisan debate concerning the

question of public versus private ownership.[1]

The setting of price or rates is a crucial decision for any public utility. Utility rates are frequently determined by non-economic considerations such as tradition and politics. While water rates may be designed to meet any of a number of different possible objectives, they have been set primarily in the past to cover the costs of operating the water system. Rates, however, have been shown to influence consumption and thus the size of the water system required per resident. Findings in previous studies on price elasticity (Table 1) ranged from -0.45 to -1.24.[2] Howe and Linaweaver have stated in their study that the demand for water, because it is influenced by the price charged, has introduced "a new dimension of complexity into the problems of efficiently designing an urban water system and determining the proper price (or prices) to be charged . . ."[3] It is imperative that officials of water supply systems know the full impact of price upon the user, since price affects consumption, which in turn affects optimum water system design, which is a determinant of the cost of the supply system.

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[1]J. W. Milliman, "Policy Horizons for Future Urban Water Supply," Land Economics, XXXIX, No. 2 (May, 1963), 110.

[2]Price elasticity is defined as:

$$N = \frac{\text{Percent change in quantity}}{\text{Percent change in price}}$$

[3]Howe and Linaweaver, "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," Water Resources Research, III, No. 1 (1967), 13.

Table 1

PRICE AND INCOME ELASTICITY FINDINGS FOR PREVIOUS RESIDENTIAL WATER USE STUDIES

Investigator	Form	Elasticity Price	Elasticity Income	R^2	Significance Level
Bain	Log	-1.10	+0.58	.69	n.s.
Fourt	Log	-0.45	-	.68	.05
Gardner	Log	-0.77	-	.83	.05
Gottlieb	Log	-1.24	+0.28	.69	-
Headley	Linear	-	+1.24	.79	.05
	Log	-	+1.37	.69	-
North	Linear	-0.67	+0.83	.69	.01
	Log	-0.61	+0.83	.68	.05

While the role of price is important in determining consumption, it is not the only factor to be considered. The role of economic analysis of water demand is to identify and interpret the relevancy and importance of all factors affecting the rate of water consumption. These variables may include home size, number of rooms per dwelling, the number and kind of water outlets, appliances, lawn area, weather conditions, and income. For example, income not only represents the ability to purchase water, but may also stand as a proxy variable for such influences as water-using appliances, number of bathrooms, and lawn area. The income elasticity of water use has been variously estimated from essentially zero to +1.37 (Column 4, Table 1).

The Problem Related to Calgary

Calgary's water supply system has been owned and

operated by the city since the first Municipal Water Works plant was originated in 1889. The primary water source for the city is the Elbow River on which the city's largest reservoir, the Glenmore Reservoir, is located.[1] Besides the Glenmore system, there are several other impounding reservoirs and wells to supply the needs of the city. The water system obtains its revenue from four sources: (1) water rates, (2) annual frontage tax, (3) fire service line charges, (4) fire hydrant rentals. In 1967 these revenues provided the water system with a surplus earnings of $1,192,575 on gross revenues of $6,524,072.[2]

Calgary's growth rate has been one of the fastest in Alberta during the past decade (Table 2). The population of Calgary has increased from 262,446 in 1961 to 330,575 in 1966. While this rate of growth represents a population increase of 26 percent, during the same time period water consumption for the city increased 30 percent (Figure 1).

Domestic water users in Calgary have their choice of how they wish to pay for their water, either by a monthly flat rate charge or by having their water metered. In 1968, 61,575 households chose flat rates and 14,755 chose meters. The ratio of the number of metered customers to the number

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[1]The Glenmore supply has an average water capacity of 17,900 acre feet or 779,724,000 cubic feet. The Glenmore pressure zone supplies approximately 40 percent of the city's population.

[2]Alberta Department of Municipal Affairs, <u>1967 Annual Report</u> (Edmonton: Queen's Printer, 1969), p. 16.

Table 2

POPULATION GROWTH OF ALBERTA CITIES
1961-1966

City	Population 1961	Population 1966	Percent Growth
Calgary[a]	262,446	330,575	26.0
Camrose	6,939	8,362	20.5
Drumheller	2,931	3,574	21.9
Edmonton[a]	314,807	376,925	19.7
Grande Prairie	8,352	11,417	36.7
Lethbridge	35,454	37,186	4.9
Medicine Hat	24,484	25,574	4.4
Red Deer	19,612	26,171	33.4
Wetaskiwin	5,300	6,008	13.3

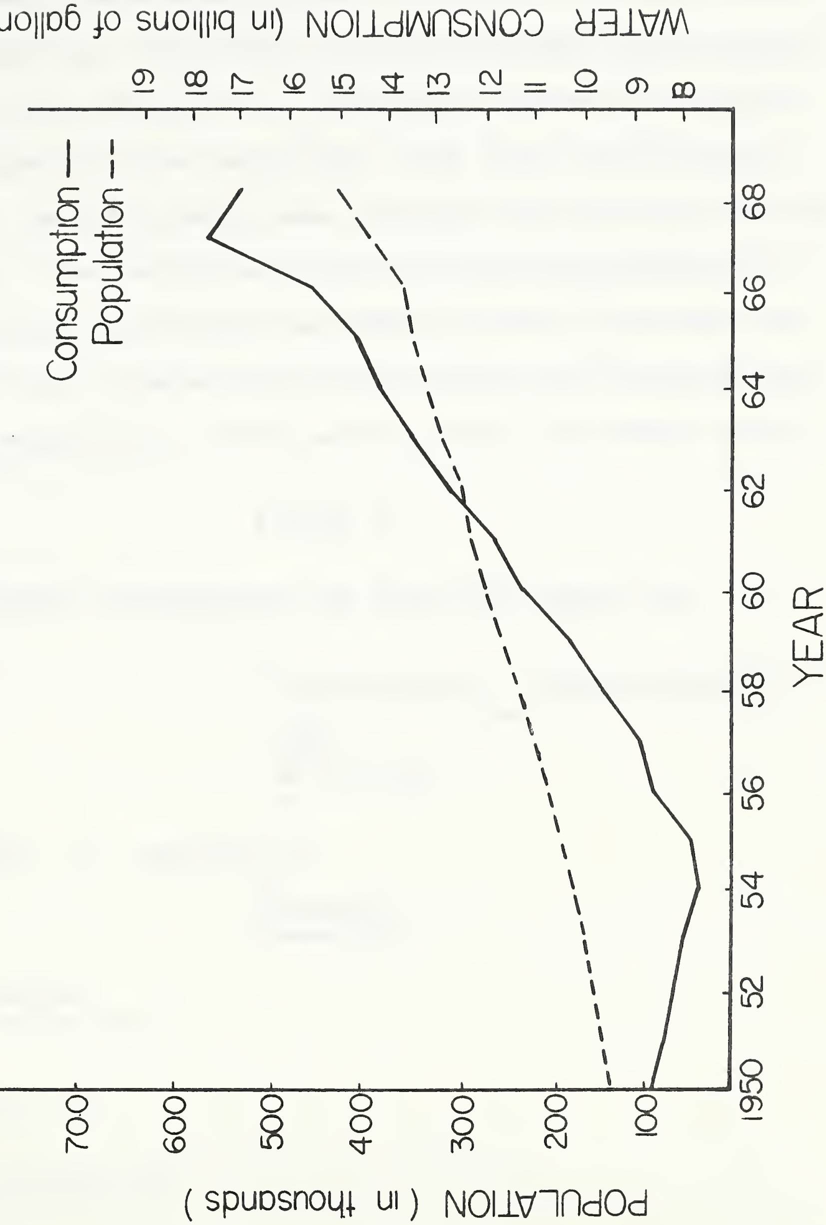
[a]Includes municipality annexed between 1961 and 1966.

Source: Canada Dominion Bureau of Statistics, Census of Canada 1966, Bulletin 1: 1-7 (Ottawa: Queen's Printer, 1966).

of flat rate customers has been fairly constant over the past few years at one to four.

Calgary's residential water users account for most of the water consumed in the city. Of the 17,225,030,000 gallons pumped in 1968, only 20.1 percent (3,467,030,000 gallons) went to commercial or industrial users, while the remaining amount went to residential users, public use, or was lost through leaks. Since residential consumers use the most water and, as will be shown, contribute the most to peaks, their consumption patterns will greatly influence the future water requirements of the water system.

Figure 1
POPULATION AND WATER CONSUMPTION PATTERNS
CITY OF CALGARY 1958-1968

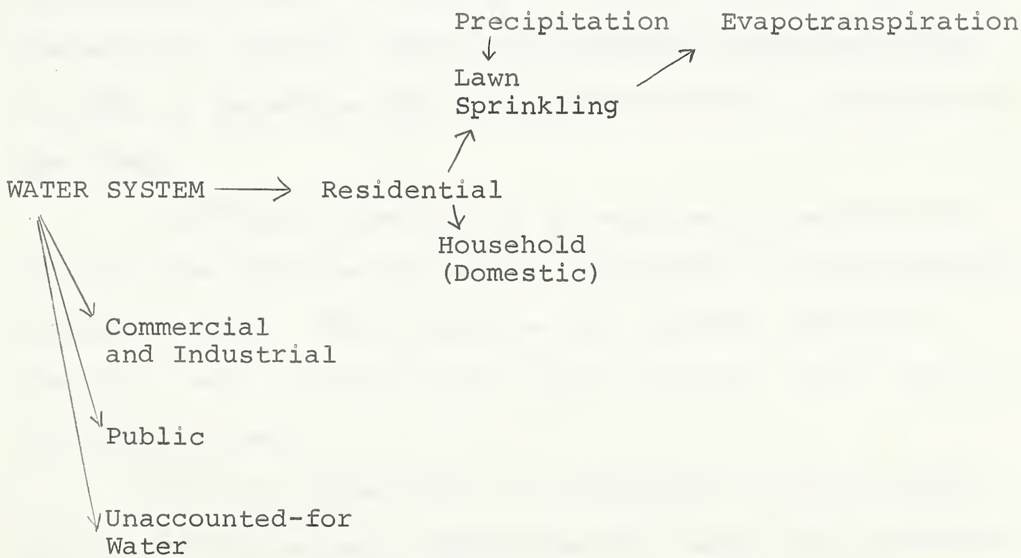


Scope of Study

Though there are many different kinds of water users in a municipality, this study is only concerned with residential water users (Figure 2). Residential water consumption may be divided into two main uses. The first is for household needs, including such uses as water for cooking, washing, and bathing. The second major use of water by households is for lawn sprinkling during the summer months. The need for lawn sprinkling is determined by the amount of precipitation and evapotranspiration which occurs during the summer months.

Figure 2

SCHEMATIC PRESENTATION OF MUNICIPAL WATER USE



Objectives

There are five main objectives for this study. The first of which is to identify and evaluate the effect of various factors affecting domestic water consumption and to estimate the parameters associated with these variables.

The second object is to determine ways of estimating water consumption from just readily available data (e.g. public records). The use of data which is easily available is of particular importance if estimation models are to be of practical use.

A third objective is to compare households choosing flat rate water pricing to those which have metered pricing. The comparison of these households will be done with respect to (a) their annual average water consumption and annual average bill, and (b) their socio-economic characteristics in order to determine why one pricing method is preferred to the other.

The fourth objective is to examine the seasonality of water use patterns and how it is related to socio-economic characteristics. This objective will provide information that will help in planning for future seasonal water peaks in residential areas.

The final objective is to determine to what extent, if any, the use of mail questionnaires biases the estimation of family and household characteristics. The findings from this objective will prove most useful for future studies which use mail surveys to obtain primary data.

Hypothesis

There are four major hypotheses to be tested in this study. The first is that water consumption by households is a function of income, or alternatively, of the value of the property. Second, water consumption is a positive function of household size and the number of appliances in the home. Third, flat rate water customers have an annual average water consumption significantly greater than metered customers. Fourth, lawn watering requirements are a function of the actual water deficit and lawn or lot size.

CHAPTER II

WATER PRICING THEORY

The Value of Water

It is well known that some of the most useful things have little value while the least useful have the most value. As Adam Smith observed:

> Nothing is more useful than water; but it will purchase scarce anything; scarce anything can be had in exchange for it. A diamond on the contrary, has scarce value in use; but a very great quantity of other goods may frequently be had in exchange for it.[1]

This "paradox of value" may be resolved by distinguishing between marginal and total utility.[2] The scarcity of a good determines the cost of that good. Because diamonds are scarce, the cost of obtaining an additional unit is high. On the other hand, water, being abundant, has a low cost for each additional unit obtained.

For a good to have value, it must be desired. There is no doubt that water, being a necessity of life, will in small daily quantities be a desired commodity. However, beyond the minimum requirements for health and sanitation water becomes a luxury item. Although the total utility (i.e. total satisfaction) increases with each additional unit

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[1] Adam Smith, The Wealth of Nations, Vol. I (London: J. M. Dent and Sons, Ltd., 1933), p. 25.

[2] For a complete discussion on the concept of marginal and total utility see Paul Samuelson, Economics, 6th ed. (New York: McGraw-Hill Book Company, 1964), pp. 427-429.

of a good obtained, it does so at a decreasing rate. However, it is not total utility that gives a good its value, rather it is the marginal unit--one unit more (or less). Classic economic theory postulates that people will purchase additional units up to the point where the utility derived from the marginal unit is equal to its cost and not beyond. The price of water then is determined by the marginal utility and marginal cost for water.

The value of water depends upon its location and physical state as well as the quantity available. Consumption in economic terms is any process altering the value of water by changing its location, physical state, or quantity. It may help to think that the value of water is related to the services to be gotten from it, not merely its physical quantity. This concept of consumption is not to be confused with the hydrological definition of consumption generally used.[1] The measure of consumption then

> . . . is not a physical but an economical one; it is the loss imposed on society by the inability to carry on some desirable uses of water in question or alternatively, the extra cost in the way of purifying processes and so forth made necessary if the subsequent uses are not abandoned.[2]

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[1]The hydrological definition of consumptive use is: "The quantity of water transpired and evaporated from a cropped area or the normal loss of water from the soil by evaporation and plant transpiration."

W. Langbein and Kathleen Iseri, General Introduction and Hydrological Definition, Geological Survey, Water Supply Paper 1541-A (Washington, D.C.: U.S. Government Printing Office, 1960), p. 6.

[2]J. Hirshleifer, et al., Water Supply (Chicago: The University of Chicago Press, 1960), pp. 66-67.

Consumer Surplus

Marshall defines consumer surplus as follows:

> We have already seen that the price which a person pays for a thing can never exceed, and seldom comes up to that which he would be willing to pay rather than go without it: so that the satisfaction which he gets from its purchase generally exceeds that which he gives up in paying away its price; and he thus derives from the purchase a surplus of satisfaction. The excess of the price which he would be willing to pay rather than go without the thing, over that which he actually does pay, is the economic measurement of this surplus satisfaction. It may be called consumer surplus.[1]

The consumer surplus of water then is the aggregate use or utility to consumers over and above the market value of the water received.[2] Water being a very useful and necessary factor to human existence has a large consumer surplus because it has traditionally been a low price commodity.[3] Since people have the privilege of purchasing water at low prices, the price quantity relationship does not reflect the

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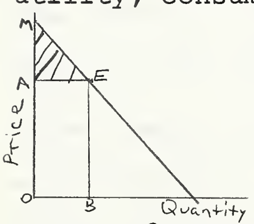
[1]A. Marshall, Principles of Economics, 9th ed. Vol. I (London: Macmillan and Co. Ltd., 1961), p. 124.

[2]In the case in which money provides a measure of utility, consumer surplus may be measured and depicted as follows. When a consumer purchases a good X in the amount of OB at OA price, he pays the total revenue OAEB; however, the commodity gives him the total utility OBEM. The shaded triangle AEM, which represents the difference between his total utility and the market value of commodity X, is his consumer surplus.



[3]Marshall points out that the estimation of the total utility for goods that are necessities of life should only be done for the units in excess of the basic requirements. Marshall, op. cit., p. 133. Hence any measurement of consumer surplus should not start at zero because the demand curve has infinite elasticity for the first few units of water taken.

full satisfaction or utility to be derived from using water. An estimation of consumer surplus of water users would add to our knowledge of the social utility of water and thereby allow an approximation of what water is worth to the consumer. Although difficult to quantify consumers surplus, treatises show it is a concept relevant for numerous social decisions.[1] Two examples will serve to illustrate the use of consumer surplus in dealing with water problems.

The first illustration and most common application of the use of consumer surplus is in the prevention of loss of revenue from water systems. Since a revenue loss may occur if a single price is charged under marginal cost pricing (see p. 15), it may be desirable to have some way to overcome this loss. Water companies, being natural monopolies, are in the position to "capture" as revenue part of what would otherwise be the consumer surplus of water users. Since water users have a large consumer surplus, they would be willing to pay even more than the marginal cost of supplying the water to them because the utility derived from the water is still greater than the price paid. Some of the methods that a water company can use to obtain additional revenues include actions such as asking for voluntary contributions, imposing a two-part tariff, and price discrimination.[2]

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[1]Paul Samuelson, _op_. _cit_., p. 437.

[2]For a more detailed description of these methods see H. Afifi, "Economic Evaluation of Water Supply Pricing in Illinois," _Journal of American Water Works Association_, LXI, No. 1 (1969); and J. Hirshleifer, et al., _op_. _cit_., pp. 91-93.

A second application of the use of consumer surplus techniques is provided by an example of the method of calculating costs for water programs. It was estimated that in New York City, which has largely a flat rate water pricing system, if the users were metered, two-hundred million gallons of water could be saved at a cost of (1) about fifty dollars per million gallons per day for metering costs, plus (2) the cost of repairing leaks, plus (3) the consumer surplus lost by restricting consumption, if the marginal cost of water was raised from zero to some positive amount (fifteen cents per one-hundred cubic feet in this case). It was estimated that the total cost of saving water, including the consumer surplus lost, was about one hundred and fifty dollars per million gallons.[1]

Average Versus Marginal Cost Pricing

There is much controversy about whether public water pricing should be based on average or marginal cost pricing. Average cost pricing where ". . . rates are obtained by dividing the system costs by the volume of water delivered . . ."[2] suggests a single price that recovers all monetary outlays for a given product. Marginal cost pricing is based on the incremental price, which is the cost for producing one additional unit of the good. However, complications may arise in defining average and marginal. For example, a cost may be a marginal

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[1]G. Stigler, The Theory of Price, 3rd ed. (New York: The Macmillan Co., 1966), pp. 80-81.

[2]C. Howe and F. Linaweaver, *op. cit.*, 15.

cost before a water system expands and an average cost after the expansion.[1]

In Figure 3 the water company is facing a situation of increasing average costs. If average cost was to be used as the basis for decision on the quantity and price to be charged, then the price that would clear the market would be OT (= AR). But does price offer the best solution? The units between OB and OA have a marginal cost greater than anyone is willing to pay. Hence production or output should be up to and not beyond the point where marginal cost is equal to price (i.e. the demand curve).

A problem may arise when the utility is faced with decreasing average costs (Figure 4). In this situation average cost output would be at OA and price OS (= AU) would be charged. However, the marginal cost output would be at a higher level than the average cost output, but the price charged would be at a lower level, causing the utility to encounter a revenue loss if they produced at OB, OG (i.e. marginal cost output and price). Average cost pricing would then be the best method if the utility were interested in covering total costs.[2] Customers, however are willing to pay

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[1]For a discussion on costs as a function of scale of output see J. Hirshleifer, et al., _op_. _cit_., pp. 94-98.

[2]An alternative to average cost pricing would be to recover losses incurred by marginal cost pricing through taxes, frontage charges, etc. The City of Calgary obtains revenue not only from actual water selling but also by having an annual frontage tax of 20 cents per foot on unimproved property and 10 cents per foot on improved property, a fire service line charge, and fire hydrant charges. Furthermore, as shown in Table 1 of Appendix B, a two part tariff is used on metered customers. A water user pays a monthly minimum amount for the first five thousand gallons of water whether he uses that amount or not.

Figure 3

PRICING UNDER INCREASING AVERAGE COSTS

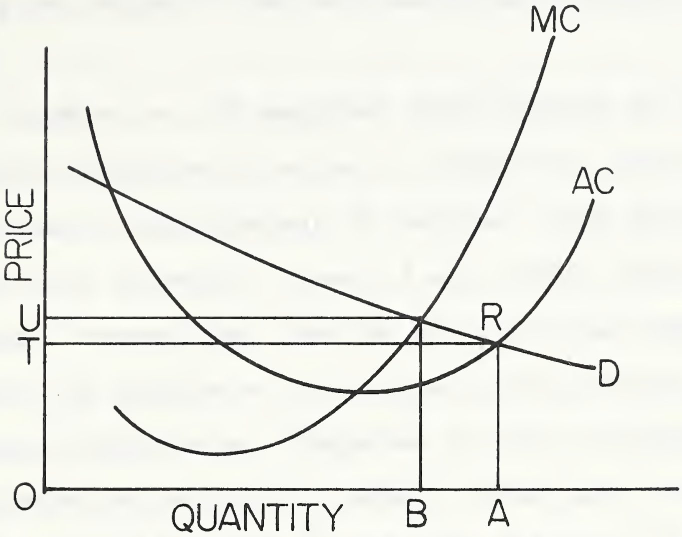
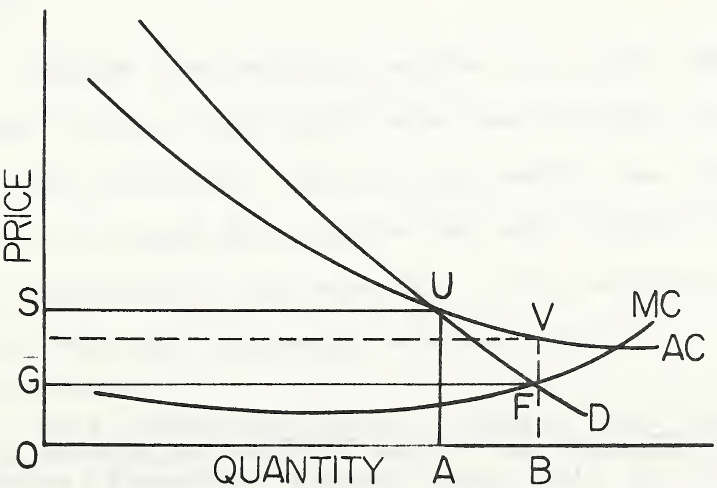


Figure 4

PRICING UNDER DECREASING AVERAGE COSTS



for additional units of water until OB is reached since the marginal cost of supplying the additional units is less than the marginal value of the additional units which the consumers desire.

Whether or not marginal cost pricing can result in the efficient allocation of water is subject to question. There are some major shortcomings of marginal cost pricing that must be taken into account. First of all, since water companies are natural monopolies, they do not have the competition to guarantee the existence of marginal cost pricing. However, competition among water companies is not a necessary condition for efficient allocation of water; if marginal cost pricing is used, it would result in the same price as if the water was sold competitively. Secondly, marginal cost pricing distinguishes the dates of particular costs. If a factor is not divisible over time, a loss will be incurred by the water company.[1]

Average cost pricing results in a price that recovers all money outlays which could have been avoided if a product had not been produced. This pricing method has been advocated because of the need for a price that will induce investment for the perpetuation and expansion of the existing plant and capacity even with decreasing average costs.[2]

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[1]M. F. Brewer, Economics of Public Water Planning, Giannini Foundation Research Report 244 (Berkeley: California Agricultural Experiment Station, May, 1961), pp. 13-14.

[2]*Ibid.*, p. 14.

With average cost pricing the water company is assured of covering costs; with marginal cost pricing the company may not cover its costs. If the water system has been expanded recently so that there is a great deal of capacity, the water company would be in a range of decreasing average costs. If marginal cost pricing were used at this time, a revenue deficit would be realized. However, with an increased demand over time full utilization of the system will occur, resulting in increasing average costs and hence a profit if marginal cost pricing is used. This cycle of decreasing and then increasing average costs is repeated whenever another major increment is added to the system.

Water Pricing Methods

Most water companies use the price system for two reasons: (1) to cover costs of the system and more recently (2) to act as a signal for economic rationing. There are three major methods of pricing that water companies may employ, each of which may be further divided.

1. Flat Rates

   A. Identical Flat Rates--Rates are the same for all customers within each class of water taker.

   B. Assessed Flat Rates--Rates are based on some predetermined criteria such as the number of rooms, washbasins, bath tubs, etc.

2. Metered Rates

   A. Uniform Rates--The same rate is charged for all quantities of water sold. The smallest water consuming customer pays the same rate per unit as the largest, with the exception that there may be a minimum rate or a service charge.

B. Block Rate or Sliding Scale--This pricing method included all those schedules of rates under which varying rates are charged according to the quantities of water drawn.

1. The Jump Scale--The quantities of water up to a certain limit are charged at a certain price; beyond that limit and inside another limit another and usually lower price is made; and so on.

2. Common Sliding Scale--The water drawn up to a certain limit is charged at a certain rate. Additional quantities are charged at a lower rate, but the higher charge on the first quantity remains as part of the bill in all cases.

C. Minimum Rates and Service Charges

1. Minimum Rate--Amount that is collected in any event though the price of the quantity of water registered by the meter amounts to less than the specified minimum rate.

2. Service Charge--A charge for the water service, which is in addition to the amount charged for water. A service charge bears some relation to a minimum rate and the two are never used at the same time.

3. Modified Minimum or Service Charge--With this form there is a minimum charge for a certain quantity of water and the amount of the minimum is made up of what would otherwise be the service charge and the meter rate for that quantity of water that is furnished for the minimum charge.

3. General Tax Fund--No water charge is billed to the customer. The cost of the system is financed through taxes. Almost all communities charge frontage charges collectable with property tax. However, few systems employ this as their only means of financing their water supply.

Flat Rate Pricing Versus Metered Pricing

Justification of Metered Pricing

Water meters in a relatively practical form first made their appearance in the United States between 1870 and 1880. The importance of water metering has long been acknowledged as the best way to handle the public water supply. Two of the primary reasons for using water meters were cited by A. Hazen:

> The first is that selling water by measurement is the only logical and fair way of conducting the business. It is the only way that does not result in gross inequalities and discriminations against some of the takers and in favor of others. The second reason is that metering water is the only practical method yet found for restricting excessive waste.[1]

When a water works system is first installed, all the plumbing fixtures in the house are new and tight. With time, rust, corrosion and other changes result in a leakage from fixtures. These small and seemingly unconsequential leaks make little impression on people, but the amount of wasted water is significant.[2] In New York City in 1951 an engineering panel stated that the largest area for improvement of

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[1]A. Hazen, Meter Rates for Water Works (New York: John Wiley and Sons, 1918), p. 1.

[2]Waste water and unaccounted-for water are two separate concepts in this report. Waste water refers just to the water people expend needlessly or carelessly in the household. Unaccounted-for water is made up of water loss not controlled by the household. The various sources of loss included under this category are: (1) leakage from the mains on the streets; (2) leakage from the service pipes between the mains and the meters; (3) under-registration of meters; (4) water used for purposes not metered (e.g. flushing of sewers); (5) seepage and evaporation from reservoirs.

existing water supplies was to reduce the waste on the premises of unmetered customers. They estimated the domestic use of water was eighty gallons per capita per day or even more, of which approximately 50 percent was highly wasteful. The high amount of waste, they concluded, was due to the fact that there was no incentive for unmetered customers to maintain, repair, or even turn off water fixtures.[1]

There are other advantages of metering that have been ignored until recently. Water pricing through the use of meters is a means to allocate or ration water. While there is nothing new about using price to ration goods, since this has always been the primary method of controlling demand in a market economy, it is a relatively new idea in water supply. If there is a shortage of water, why not increase the price so as to decrease the quantity demanded? Although pricing is not the only solution to the problem of shortages, it is an easy method, it is equitable for all consumers, and it can be enacted almost instantly.

Metering of water also presents a solution to the problem of seasonal peaking.[2] During the months when the problem of peaking is most serious, the rate schedule for metered water users may be increased to discourage nonessential use of water. At present there is no method of providing an incentive to avoid short period (e.g. day, hour)

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[1] J. Hirshleifer, et al., op. cit., pp. 260-261.

[2] The problem of peaking is discussed in more detail later in this chapter.

peaks. A solution to these peaks may lie in the use of demand meters, which are not available on a low cost basis at present.

Another argument for metering rests on the notion of substitutability of other goods and practices for water. If people have to pay for the actual amount of water they use, they will not be as likely to use as much water for non-essential reasons. For example, water users may employ better water management practices such as less frequent and more efficient lawn sprinkling, repairing leaks, and using shrubs and bushes requiring little water.

<u>Justification of Flat Rate Pricing</u>

Metered rates presently in use are quite often not equitable or "fair." Unfair rates may be due to the fact that there is lack of agreement on exactly what are fair rates, or it may be caused by the influence of certain classes of water takers who are opposed to fair rates for all water users. While the above argument may have some merit, it is most likely that the metered rates are less discriminatory than the use of identical flat rates usually employed in the absence of metered rates.

A more rational argument can be made for a flat rate pricing system by showing that the extra costs of employing a metered system are less than the benefits received from such a system. However, as one author points out:

> The validity of this argument depends upon the magnitude of the cost of administering a metered system in comparison with the loss in welfare [= total utility]

> resulting from using a non-price rationing mechanism to allocate a fixed supply of water. The loss in welfare in the case of non-price rationing results from the fact that the marginal value in use might not be equal for all consumers if the scale of development of the water system is not adequate to supply the entire market demand at a zero price.[1]

While the defense of identical flat rates must rest entirely on its simplicity and low operational cost, an assessed flat rate system, if properly enacted, would be based on known variables (and their parameters) affecting water consumption. Hence, water consumers would be paying an amount that is related to their fair share of the cost of providing water. Assessed rates, while more favorable than identical flat rates, do have the shortcoming of being a rate not exactly equivalent to the actual amount of water used (and wasted). Hence in comparison to metered pricing little incentive is provided to avoid wasteful uses of water in the home. Assessed flat rates have one advantage: They may be devised to make the people who contribute more to water peaks than others pay for their burden on the water works. Yet while assessed flat rates seem to be an appropriate method to make households pay for their share of having the water system built to meet peak demands, they do not give the water company any method of regulating the peaks.

Price Discrimination

A water company, which is a natural monopoly, is in

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[1]L. Falkson, Water Shortages and Pricing, Proceedings of the Third American Water Resources Conference (San Francisco, November, 1967), p. 254.

the position to practice price discrimination and thereby prevent the marginal value in use from being equal for all consumers.[1] Price differences, however, do not necessarily imply that price discrimination is being practiced. A different price for water for an individual is justified if the seller incurs a different cost of delivery and/or processing.

Sometimes where pricing has failed to recover the costs of operating the water system, price discrimination may be "justified" by the operators of the system. Customers are classified into different markets, and the price charged for water varies from market to market to capture part of the "consumer surplus" of the customers of each separate market. Quite often large users of water try to justify a low rate because of savings in pipe lines. Hirschleifer, however, disagrees:

> . . . once the pipes are in, the unit marginal cost of serving customers is almost independent of volume taken. A lower rate therefore leads to wasteful use of water by large users, since small users would value the same marginal unit of water more highly if delivered to them.[2]

Hirschleifer believes that the cost of installing the pipes should be assessed as a one time charge (or an annual charge independent of water consumed) against the outlet served. While this idea is interesting, this writer believes that there are economies of scale involved here that may justify

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[1]Price discrimination is the situation when a seller charges different prices to different users, or the same user for varying quantities of the same commodity.

[2]J. Hirshleifer, et al., op. cit., p. 46.

a lower rate for large users. The economies of scale do not lie just with the pipes and their installation but also with pumpage and treatment facilities. However, a study of the costs and scale of water supply systems is outside the scope of this study.

The Problem of Peaking

Although a water system must rely on the average use of its customers for its revenue, the system itself must be built to serve peak demands of its customers. Peaking, which occurs daily and hourly as well as seasonally, has been the subject of much needed research in recent years.[1] Wolff in 1956 found that average demands were exceeded in peak months by 40 percent, on peak days by 62 percent, and peak hours by 157 percent. He has also found that peaks have been increasing at a rate of 1 percent a year in the ratio of peak day to the average day.[2]

A user with a large water connection, while contributing more to peaking problems than a user with a smaller connection, may pay the same bill for water used, if both use the same total amount of water during the billing cycle. A common practice is to charge a fixed amount based on the size of the connection on the theory that size of connection places a technical limit on the rate of water use. This method,

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[1]Data on peak consumption for the City of Calgary is given on page 87.

[2]J. Milliman, _op_. _cit_., 120-121.

while increasing the system's revenue, does not satisfactorily control peaking problems because it utilizes a fixed charge. Ideally demand meteres should be used with a different price for peak and non-peak hours and days. At present, however, the type of meter needed for this type of pricing is too expensive for practical use.

Seasonal peaking is associated with summer lawn watering. While industry and commercial establishments contribute to the high summer demand for water, it will be shown that the single-dwelling household unit contributes most heavily to the seasonal demands on the water system. Furthermore, to make matters more critical, summer peaks are usually when many systems (not including Calgary) have their lowest water reserves. Fortunately, the problem of seasonal peaking can be handled more easily than the daily and hourly peaking problems if a metered system is in operation. By setting a higher rate during the summer months, the rationing of water could take place with very little trouble. Even if a metered system does not exist, control of lawn sprinkling (the major contributor to seasonal peaks) can be undertaken by non-pricing methods to alleviate the peak demands.

Pricing and Equity

Utility rates should have two primary objectives. The first is to cover costs of operating the system and the second to be equitable to all users (i.e. all users pay their share). It is the latter of these two objectives about which little has been written; moreover, public utilities have not

paid enough attention to it.[1] At present, all water pricing methods have problems of producing equitable rates for the water user.

The problems of an equitable pricing method are most obvious for an identical flat rate pricing system. With this method of charging all domestic water users pay the same amount of money for the right to have water. But is it fair that a person with a small family, few water using appliances, and a small lawn should pay the same rate as a large family with numerous water using appliances and a large lawn area? That is, should a user who consumes less water and contributes less to peaking pay the same rate as a user who consumes a greater amount of water and more importantly contributes to a greater extent to the peaks of the system?

Assessed flat rates that presumably are based on some predetermined factors highly correlated with water consumption do provide a more equitable method of rate setting between socio-economic classes than identical flat rates. People could be charged on a basis of their ability to contribute to peaks as well as consume water. Customers under this system would pay their fair share of the capital expense that was invested in order to make the water system able to meet

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[1]The desire for equitable rates has been extended to sewage rates. On the premise that people should pay according to how they deteriorate the water, Deck and Lawson have suggested a method of financing sewage treatment by assessing the users in proportion to their use. See N. Deck and P. Lawson "Pollution Control as a Public Utility," Water and Pollution Control, CVI, No. 3 (March, 1968), 32-34. The City of Edmonton charges major industrial users according to the solid matter content of sewage discharged into the public system.

peak demands. Though the assessed rates are equitable for different socio-economic classes, they may still not be equitable for users within the same socio-economic class. Two households may have the exact same socio-economic characteristics, but because of personal habits one household consumes more water than the other while both pay the exact same amount for their water.

While metered rates are generally considered the most equitable method of pricing, this method of rate setting is by no means perfect. Metering while allowing each customer to pay for the actual amount of water used has no way of making people who contribute the most to peaking pay for their share of the cost incurred to have the system built to meet peak demands. Often the utility tries to cover the capital expenses of building to meet peaks by imposing a minimum charge.[1] An identical minimum charge is, in effect, an identical flat rate tariff superimposed upon the metered rate structure. If the minimum charge is high in relation to the rate imposed according to use and if the water quantity allowed under the minimum before additional rates are charged is high, the rate structure takes on all the attributes of an identical flat rate system with many of its inequities,

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[1]The City of Calgary imposes a minimum charge of $3.10 per month with an allowance of 5,000 gallons or 800 cubic feet under this minimum charge. This amount is double the 400 cubic feet reported in a United States survey. See. H. Seidel and J. Cleasby, "A Statistical Survey Analysis of Water Works for 1960," Journal of American Water Works Association, LVIII, No. 12 (December, 1966), 1516. The City of Edmonton also allows 400 cubic feet under its minimum monthly charge.

especially for small water users. Such a pricing system then merely curbs the excesses of water waste.

Demand Determinants

The primary influencing factors affecting residential water use are: (1) economic level of the consumer, (2) climate, and (3) whether consumers have metered or flat rate service.[1]

In order to limit the number of water using determinants in the study only certain variables were considered for analysis. A variable was chosen, if it was one of the items used in assessing the flat rates in Calgary; if it has been shown to be an important factor in previous studies; if, because of a priori reasoning, it was felt to be an important variable. The following variables were selected for study.

Number of Persons in the Household

The more people residing within one household, the greater the amount of water to be delivered to that house in order to meet basic water requirements (i.e. non-sprinkling demand of the household). The number of people in the household has been shown in previous studies to be one of the primary variables affecting residential water use and similar results are expected here.[2]

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[1]F. Linaweaver, et al., "Summary Report on the Residential Use Research Project," Journal of American Water Works Association. LIX, No. 3 (March, 1967), 272.

[2]See for example, R. North, "Consumer Responses to Prices of Residential Water," American Water Resource Conference, (San Francisco, 1967); D. Dunn and T. Larson, "Relationship of Domestic Water Use to Assessed Valuation with Selected Demographic and Socio-Economic Variables, Journal of American Water Works Association, LV (1963), 441-450.

Income

Family income is a constraint on the amount of goods and services that may be obtained for the household. If water is a superior good (as opposed to a "Giffen" good),[1] it is hypothesized that people with higher incomes will use more water than those with low incomes. Stated differently, it is hypothesized that the demand for water is a function of the ability to pay for that commodity.

Market Value and Assessed Value of Home

Since people tend to live in homes whose value bears some relation to their income, the value of their property should prove to be a surrogate (or "proxy" variable) for family income. In fact, market value of the home has been shown by North to be more closely associated with water consumption than income.[2] The major hypothesis for these two variables is that there is a direct relationship between water consumption and home value. Also to be tested is a sub-hypothesis that market value of the home as estimated by the occupant and assessed value of the home as determined by an assessor are suitable alternates of measurement of water use.

Lawn Area

Water is used outside the home especially in the summer months for lawn irrigation. Howe and Linaweaver in their study in the United States have found lawn area to be one of

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[1]P. Samuelson, op. cit., p. 432.

[2]North, op. cit., p. 8.

the prime determinants of urban water consumption and contributors to summer peaks.[1] Since the larger the lawn area, the more area there is to be watered it is hypothesized that there is a direct relation between lawn area and summer water consumption. Because the use of water for lawn sprinkling is not essential, the demand for summer sprinkling water should prove more elastic than the demand for indoor water use. The substitutability of lot area for lawn or non-building area will also be investigated because the former of the two variables is more easily available than the latter.

Water Deficit

The amount of water needed for lawn watering depends greatly on the existing weather conditions, especially temperature and precipitation. While precipitation adds moisture to the ground, thereby reducing the need to water the lawn, evapotranspiration takes moisture away from the ground, increasing the need to water if the lawn is to be kept green.[2] Howe and Linaweaver have pointed out that "sprinkling demands follow potential evapotranspiration quite closely when antecedent precipitation has been dissipated."[3] It is not then the absolute amount of evapotranspiration or precipitation that effects the amount of lawn watering but rather the water

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[1]C. Howe and F. Linaweaver, op. cit.

[2]A detailed synopsis including the definition and method of calculating evapotranspiration is given in Appendix A.

[3]Howe and Linaweaver, op. cit., 4.

deficit. The water deficit may be expressed algebraically as:

$$W = P - E$$

Where W = Monthly Water Deficit (inches)

P = Monthly Precipitation (inches)

E = Monthly Evapotranspiration (inches)

By multiplying the lawn area of a household by the water deficit for the given time period, the resulting water deficit per unit area may be introduced into a linear demand model. Since the amount of water the lawn needs to be kept green depends upon the existing water deficit, it is expected that water consumption will vary directly with the water deficit during summer months.[1]

Number of Water Using Appliances and Installations

The greater the number of water using appliances and fixtures in a home, the more ways a household has to use water. A purpose of this study is to see if and by how much the number of water using appliances and fixtures relate to water use.[2] In addition, since the City of Calgary uses water fixtures and appliances in their water assessments of flat rate customers (Appendix B, Table 1), the rational behind Calgary's assessment formula must be examined. A third objective is to explore the relation, if any, between home value and number of appliances and fixtures. It is expected that there is a

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[1] Because this study is an intra-city study the water deficit will be essentially the same for all residents for any given time period.

[2] Water using appliances include washing machines, automatic garbage disposals, and dishwashers. Water using fixtures include bathtubs and showers, washbasins and sinks, toilets and other water taps (e.g. outside connections).

high positive correlation between number of appliances and fixtures with the value of the home.

Metered or Flat Rate Service

Recent studies in the United States have shown that meters, while having little influence on household use, do have a considerable effect on summer sprinkling. Howe and Linaweaver found the average annual household use for metered and flat rate households was 206 and 197 gallons per day per dwelling, respectively, while the annual average sprinkling use for each pricing area was calculated at 155 and 350 gallons per day per dwelling unit.[1] As a result of the high sprinkling rate both the flat rate areas maximum day and peak hour demands were more than double that of metered areas. A complete summary of water use in the two different pricing areas as compiled by Howe and Linaweaver is given in Table 3.

The City of Calgary's dual water pricing method allows for a unique comparison of metered and flat rate customers under identical conditions. Although available data only allows for a comparison of the two groups over an entire year, it is hypothesized that the flat rate customers do have a substantially higher average annual rate of water consumption than metered customers.

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[1]Howe and Linaweaver, op. cit., 14.

Table 3

PREVIOUS FINDINGS OF WATER USE
IN METERED AND FLAT RATE AREAS
(OCTOBER, 1963 THROUGH SEPTEMBER, 1965)

	Metered Areas	Flat Rate Areas
	(Imperial Gallons per Day per Dwelling Unit)	
Annual Average		
Leakage and Waste	21	30
Household	206	197
Sprinkling	155	350
TOTAL	381	576
MAXIMUM DAY	815	1960
PEAK HOUR[a]	2066	4305

Source: Howe and Linaweaver, op. cit., 15.

[a]The peak hourly rate was multiplied by 24 to obtain daily rates consistent with other entries in the table.

CHAPTER III

DATA COLLECTION AND SAMPLE RELIABILITY

Household Survey

Selection of Sample

Cross-sectional data (i.e. data relating to a specific period in time) analysis was chosen for the study of variation in water use within Calgary since factors affecting water consumption change little over time. The time period used in this study is October, 1967, through September, 1968. This time period not only allows the use of recent data but also allows the study of one entire summer. The inclusion of an entire summer time period is essential if the importance of sprinkling demands for water is to be estimated.

Households to be studied were selected randomly from all domestic water users in Calgary. A stratified two-stage sample of households from the water accounts of the Consumer Service Department was drawn in August of 1968. The following procedure was used in obtaining the samples. First, the pages to be sampled in each water account book were chosen from a list of random numbers.[1] This procedure allowed for a representative sample of all sections of the city. The second step was to take from each of the pages chosen at random the

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[1]All water accounts for Calgary were kept in nineteen different account books, called cycles; each cycle representing a different section of the city.

first two domestic flat rate customers and the first metered customers listed. Totally 523 flat rate customers and 175 metered customers were drawn by this procedure.

Because the usable responses from metered households proved too small, a supplementary sample of metered customers was drawn in the spring of 1969. This sample involved taking the second metered customer, if one were listed, on the pages from which the main sample had been drawn. The total number of metered customers drawn in the supplementary sample was 117. The final sample contained 815 households, of which 292 were metered customers and 523 were flat rate customers.

Primary Data

For each household selected in the survey a short questionnaire was sent to obtain the following information:[1]

(1) Number of people who lived in the home,
(2) Number of rooms in house,
(3) Number and kind of water using appliances and fixtures,
(5) Size of lawn and garden area,[2]
(6) Gross family income.

Secondary Data

Public Records supplied further data on each household. The additional information obtained through the Consumer Service Department and Land Assessment Department for each household in the sample was:

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[1]A copy of the questionnaire is presented in Appendix B.

[2]Respondents' estimates of areas were quite unreliable. Ultimately area measurements were taken from the Land Assessment Department.

(1) Lot size of all customers,
(2) Building area of all customers,
(3) Assessed value of lot of all customers,
(4) Assessed value of buildings of all customers,
(5) Monthly water consumption for metered customers,
(6) Monthly water charge for all users,
(7) Monthly sewage charge for all users.

Household Survey Procedure

One week before the questionnaire was sent to the households in the sample, a notice of the project was placed in the two Calgary daily newspapers. The notice that ran in the Wednesday and Saturday papers told of the forthcoming questionnaire as well as the overall project being undertaken in the city.[1]

A short letter explaining the survey's importance accompanied the questionnaire each household received; they also received a business reply envelope. The questionnaire was coded on the back in order to match it up with the secondary data obtained for that particular household. The people who did not respond to the first questionnaire received a follow-up questionnaire in the mail. If the second questionnaire was still not returned, a personal interview was conducted at that particular home.

Response to Questionnaire

General Reaction

Table 4 summarizes the overall response to the household questionnaire. Of the 815 households contacted, only

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[1]A copy of the advertisement is presented in Appendix B.

Table 4

GROSS SAMPLING RATES FOR HOUSEHOLD QUESTIONNAIRE
CITY OF CALGARY, 1968-1969

Sample Classification	Total Gross Sample	Mail Response	Personal Interview Response	Unobtainable Response	Refused Response
TOTAL					
Number	815	532	92	133	58
Percent of Total	100.0	65.3	11.3	16.3	7.1
FLAT RATE CUSTOMERS					
Number	523	354	48	92	29
Percent of All Flat Rate Customers	100.0	67.7	9.2	17.6	5.5
Percent of Total Sample	164.2	43.4	5.9	11.3	3.5
METERED CUSTOMERS					
Number	292	178	44	41	29
Percent of All Metered Customers	100.0	60.9	15.1	14.0	9.9
Percent of Total Sample	35.8	21.8	5.4	5.0	3.5

7.1 percent refused to answer the questionnaire, while 76.6 percent (mail plus personal interview responses) gave some if not all the desired information. Furthermore, of the 624 households completing the questionnaire, 532 (85 percent) did so by mail.

Metered Versus Flat Rate Customer Response

Flat rate customers as indicated in Table 4 were generally more responsive to the household questionnaire than were the metered customers. Approximately 6 percent of the flat rate customers refused to answer the questionnaire, while almost 10 percent of the metered customers refused to comply with the survey. Furthermore, 68 percent of the flat rate customers returned the mail questionnaires, while only 61 percent of the metered customers returned mail questionnaires.

Complete Versus Incomplete Replies

Respondents were hesitant in answering two questions --their gross family income and market value of their home. As shown in Table 5, about three quarters of the people who replied by mail gave their income; about seven-eighths gave the market value of their home. Primarily respondents did not answer these questions because they did not understand the question's importance to the study. On numerous returned questionnaires, on which all information was given except family income and, or home market value, the respondent had stated that this question (or these questions) had nothing to do with water use.

The percentage of people answering the questions on market value and gross family income is significantly smaller

Table 5

RESPONSE TO QUESTIONS ON MARKET VALUE AND INCOME
CITY OF CLAGARY, 1968-1969[a]

	Metered Customers[b]	Flat Rate Customers[b]
Mail Returns		
Market Value		
Number	158	297
Percent of group	88.8	83.9
Income		
Number	132	253
Percent of group	74.1	71.5
Personal Interview		
Market Value		
Number	26	27
Percent of group	59.1	56.2
Income		
Number	23	27
Percent of group	52.3	56.2

[a]Based on all questionnaires filled out in whole or part.

[b]The Chi^2 value for the difference between mail and personal interview responses was calculated as 7.364 for metered customers and 5.666 for flat rate customers.

for the personal interview group than for mail respondents. The personal interview group, consisting of people who twice refused to return the questionnaire by mail, had only 59 percent of its metered customers and 56 percent of its flat rate customers giving market value and 52 percent of metered and 56 percent flat rate customers giving their income.

The number and percentage of customers who completed all information on the survey questionnaire is given in Table 6.[1] Approximately one half of the entire sample, or two thirds of the people who did fill out the questionnaires, gave complete information.

While the difference in complete sampling rates between metered and flat rate households is not large, there is a significant difference in the complete sampling rate between mail and personal interview responses. Seventy percent of the flat rate customers and 73 percent of the metered customers replying by mail gave complete information; only 35 percent of the former and 39 percent of the latter gave complete information upon being personally interviewed.

Effective Sampling Rate

The effective sampling rate is defined as:

$$\text{Effective Sampling Rate} = \frac{\text{number of usable returns}^{1}}{\text{number of households in universe}}$$

The effective sampling rates for this study are given in Table 7. Although metered customers had a higher effective

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[1]Usable returns is defined as questionniares which had information for all the questions asked, with the exception of the question on lawn and garden area.

Table 6

COMPLETE RESPONSE RATES FOR HOUSEHOLD QUESTIONNAIRE
CITY OF CALGARY, 1968-1969

Response Classification	Total Sample	Mail Response	Personal Interview Response
TOTAL			
Number	412	378	34
Percent of Total Responses	66.0	60.6	5.4
Percent of Total Sample	50.5	46.4	4.2
FLAT RATE CUSTOMERS			
Number	265	248	17
Percent of All Flat Rate Responses	--	70.0	35.4
Percent of All Flat Rate Customers	50.7	47.2	3.2
Percent of Total Response	42.5	39.7	2.7
Percent of Total Sample	32.5	30.4	2.1
METERED CUSTOMERS			
Number	147	130	17
Percent of All Metered Responses	--	73.0	38.6
Percent of All Metered Customers	50.3	44.5	5.8
Percent of Total Response	23.5	20.8	2.7
Percent of Total Sample	18.0	15.9	2.1

sampling rate, this group also had a greater proportion of its population sampled. The proportion of metered customers sampled to the total number of metered customers was twice that of the flat rate customers. There were 14,737 metered accounts, of which 292 were sampled (i.e. 2.0 percent of the total); only 523 flat rate customers were sampled out of 56,648 flat rate accounts (i.e. 1.0 percent of the total).

TABLE 7

EFFECTIVE SAMPLING RATES OF METERED AND FLAT RATE CUSTOMERS
CITY OF CALGARY, 1968-1969

Sample Group	Total Effective Sample	Mail Respondents	Personal Interview Respondents
Metered Customers			
Number	147	130	17
Percent of Universe	.99	.88	.11
Flat Rate			
Number	265	248	17
Percent of Universe	.46	.43	.03

Comparison of Sub-sample Groups

Sub-sample Classification

The two sample strata; (metered and flat rate customers) were subdivided into six sub-sample groups: (1) mail respondents giving complete information; (2) mail respondents giving only part of the information requested; (3) personal interview respondents giving complete information; (4) personal interview respondents not giving the complete

information requested; (5) households not sending back a questionnaire and not home when contacted; (6) households refusing either through the mail or personal interview to answer any of the questions on the survey questionnaire.

The reasons for the above classifications are twofold. First, there is the need to separate out the households with complete information for multi-variate statistical analysis. Secondly, grouping of households is necessary to check for sampling bias or distortion due to selective returns. The problem of bias will be dealt with in the following two sections of this chapter under the two major kinds of bias encountered in surveys-response and non-response bias.[1]

Response Bias

A response bias may exist in a survey because people participating in the study answered questions incorrectly. Incorrect or mischievous answers may arise in any kind of survey, whether it be conducted by mail, telephone, or personal interview.

While response bias due to inaccurate replies cannot be checked, the consistency of replies can be checked through the use of secondary data. Tables 8 and 9 indicate that secondary data follows similar patterns as the primary data. That is, the sub-sample whose primary data indicates a lower

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[1]A comprehensive list and discussion of the different biases arising in a survey, as well as other sources of errors encountered by a survey, are given in R. Ferber and P. Verdoorn, Research Methods in Economics and Business (New York: Macmillan and Co., 1962), p. 258-261.

Table 8

DIFFERENCE BETWEEN SAMPLE MEANS
COMPARISON WITH COMPLETE MAIL RESPONDENTS
METERED CUSTOMERS, CITY OF CALGARY

Item	Mail Partial Response		Personal Interview Complete Response		Personal Interview Partial Response		Unobtainable Response		Refused Response	
	Difference Absol.	Rel.	Difference Absol.	Rel.	Difference Absol.	Rel.	Difference Absol.	Rel.	Difference Absol.	Rel.
FAMILY CHARACTERISTICS										
No. of Persons	-0.34	-9.16%	-0.42	-11.3%	0.44	11.9%	(NOT AVAILABLE)			
Income ($)	377	3.2	-4241**	-36.5	-6023**	-51.8				
HOUSEHOLD CHARACTERISTICS										
Rooms	-0.36	-5.2	-.82*	-11.9	-0.81**	-11.8				
Washing Mach.	0.05	5.1	0.03	3.2	0.01	1.0				
Auto. Gar. Disp.	0.07	43.7	0.01	8.6	0.02	12.5	(NOT AVAILABLE)			
Dishwashers	-0.02	-11.8	-0.05	-30.2	-0.02	-11.8				
Tubs/Showers	1.13	2.4	0.18	12.2	0.20	13.6				

continued

Table 8 (continued)

Item	Mail Partial Response: Difference Absol.	Rel.	Personal Interview Complete Response: Difference Absol.	Rel.	Personal Interview Partial Response: Difference Absol.	Rel.	Unobtainable Response: Difference Absol.	Rel.	Refused Response: Difference Absol.	Rel.
Basins/Sinks	0.06	1.9	-0.58**	-18.6	-0.37°	-11.9				
Toilets	0.05	2.9	-0.13	-7.8	-0.16	-9.3				
Other Taps	-0.56**	-26.4	-0.83**	-39.0	-0.27	-12.7	(NOT AVAILABLE)			
Market Value ($)	2673	12.2	-3106	-14.1	2345	10.7				
Land Asses. ($)	-37	-1.7	-291	-13.7	73	3.4	-202	-9.5	-41	-1.9
Bldg. Asses. ($)	-204	-4.0	-1127*	-21.9	-99	-1.9	232	4.5	-126	-2.5
Lot Size (sq. ft.)	24	0.4	-780*	-12.4	72	1.1	-570	-9.1	156	2.5
Bldg. Area (sq. ft.)	-66	-5.1	97	7.5	33	2.6	-74	-5.7	-69	-2.3
WATER CONSUMPTION (GALLONS)										
Oct. 1967	-1712*	-27.2	-1824*	-29.0	-1480°	-23.5	-645	-10.2	-1402°	-22.3
Nov. 1967	969	22.3	1950	44.9	-418	-9.6	681	15.7	477	11.0

continued

Table 8 (continued)

Item	Mail Partial Response Difference Absol.	Mail Partial Response Difference Rel.	Personal Interview Complete Response Difference Absol.	Personal Interview Complete Response Difference Rel.	Personal Interview Partial Response Difference Absol.	Personal Interview Partial Response Difference Rel.	Unobtainable Response Difference Absol.	Unobtainable Response Difference Rel.	Refused Response Difference Absol.	Refused Response Difference Rel.
Dec. 1967	383	8.0	-511	-10.6	-1.10°	-22.9	245	5.1	195	4.1
Jan. 1968	-1322*	22.9	-1289°	-22.4	388	6.7	142	2.5	-1153°	-20.0
Feb. 1968	331	6.6	448	8.9	-356	-7.1	-459	-9.1	-94	-1.9
Mar. 1968	-109	-2.0	759	14.2	-63	-1.2	1538	28.7	-430	-8.0
April 1968	-1191	-15.9	-2092*	-27.9	-1023	-13.6	-1153	-15.4	-40	-0.5
Winter (Oct. 1968-Sept. 1968)	-2161	-5.6	-2070	-5.4	-3562	-9.2	-721	-1.9	-3220	-8.3
May 1968	-1383	-14.4	-847	-8.8	-1945	-20.2	-2207°	-23.0	-1255	-13.1
June 1968	-172	-2.0	-692	-8.1	-241	-2.8	318	3.7	1569	18.3
July 1968	-304	-2.8	-3136**	-29.1	-875	-7.9	-894	-8.3	146	1.3
Aug. 1968	-1223	-11.0	-4081**	-36.6	-2659*	-23.9	-946	-8.5	-1533	-13.8
Sept. 1968	-2019*	-23.1	336	3.8	236	2.7	-1213	-13.9	-84	-1.0

continued

Table 8 (continued)

Item	Mail Partial Response Difference Absol.	Rel.	Personal Interview Complete Response Difference Absol.	Rel.	Personal Interview Partial Response Difference Absol.	Rel.	Unobtainable Response Difference Absol.	Rel.	Refused Response Difference Absol.	Rel.
Summer (May 1968-Sept. 1968)	-4373	-9.1	-7866*	-16.5	-4378	-9.2	-4802	-10.0	-69	-0.1
Annual (Oct. 1968-Sept. 1968)	-6534	-7.6	-9935°	-11.5	-7940	-9.2	-9713	-11.2	-4933	-5.7
AMOUNT PAID FOR WATER ($)										
Oct. 1967	-0.53	-12.5	-0.60°	-14.3	-0.55	-13.0	-0.05	-1.2	-0.47°	-11.0
Nov. 1967	0.85	24.3	-0.84	-27.0	-0.15	-4.3	0.39	11.3	0.11	7.2
Dec. 1967	0.21	5.6	-0.26	-6.7	-0.40°	-10.4	-0.01	-0.4	-0.02	0.5
Jan. 1968	-0.52*	-12.6	-0.61*	-14.7	-0.37	-8.9	0.11	2.7	-0.46°	-11.2
Feb. 1968	0.22	6.2	0.21	5.9	-0.02	-0.0	-0.09	-2.5	0.06	1.5
Mar. 1968	-0.09	-2.2	0.19	4.9	0.02	-0.0	0.69	17.7	0.83	21.3
April 1968	-0.46	11.0	-0.67°	16.0	0.64	15.3	-0.16	-3.9	-0.25	-6.0

continued

Table 8 (continued)

Item	Mail Partial Response		Personal Interview Complete Response		Personal Interview Complete Response		Unobtainable Response		Refused Response	
	Difference		Difference		Difference		Difference		Difference	
	Absol.	Rel.	Absol.	Rel.	Absol.	Rel.	Absol.	Rel.	Absol.	Rel.
Winter (Oct. 1968-April 1968)	-0.15	-0.6	2448	6.3	0.02	0.1	-1099	-2.8	-3598	-9.2
May 1968	0.02	0.5	-0.05	-1.1	-0.48	-10.8	-0.51°	-11.6	-0.24	-5.6
June 1968	0.00	0.01	-0.17	-4.1	-0.15	-3.6	0.08	2.0	0.40	9.7
July 1968	-0.32	-6.6	-1.00**	-20.3	-0.29	-5.9	-0.34	-7.0	-0.13	-2.7
Aug. 1968	-0.33	-6.7	-1.06**	-22.3	-0.64°	-12.9	-0.44	-8.9	-0.59	-11.8
Sept. 1968	-0.48°	-10.9	0.02	0.5	0.28	6.3	-0.34	-7.7	-0.17	-3.9
Summer (May 1968-Sept. 1968)	-1.11	-4.8	-8885*	-18.2	-1.29	-5.6	-5821	-11.9	-3598	-0.2
Annual (Oct. 1967-Sept. 1968)	-1.09	-2.2	-11332	-12.9	-1.09	-2.2	-11110	-12.7	88	7.2

continued

Table 8 (continued)

NOTES: [a]Superscripts indicate probability that samples are drawn from different populations:

**	99%
*	95%
°	90%

No superscript probability under 90%

Students t test employed according to G. Snedecor, <u>Statistical Methods</u>, 5th ed. (Ames: The Iowa State College Press, 1957) p. 98.

[b]Number of observations, group means and population standard deviations, see Appendix B, tables 2 and 3.

Table 9

DIFFERENCE BETWEEN SAMPLE MEANS, COMPARISON WITH COMPLETE MAIL RESPONDENTS FLAT RATE CUSTOMERS, CITY OF CALGARY

Item	Mail Partial Response		Personal Interview Complete Response		Personal Interview Partial Response		Unobtainable Response		Refused Response	
	Difference Absol.	Rel.	Difference Absol.	Rel.	Difference Absol.	Rel.	Difference Absol.	Rel.	Difference Absol.	Rel.
			FAMILY CHARACTERISTICS							
No. of Persons	-0.31	-7.6%	-0.02	0.4%	-0.24	-5.9%	(NOT AVAILABLE)			
Income ($)	11,598	112.6	-708°	6.9	-3858**	-37.4				
			HOUSEHOLD CHARACTERISTICS							
Rooms	-0.84**	-12.8	0.01	0.1	-0.68*	-10.3				
Washing Mach.	-0.01	-1.0	0.02*	2.5	-0.01	-1.0				
Auto. Gar. Disp.	-0.07°	-41.2	0.003	1.7	-0.07	-41.2	(NOT AVAILABLE)			
Dishwashers	-0.03	-16.17	0.05	29.8	-0.12**	66.7				
Tubs/Showers	-0.01	-0.7	-0.04	3.1	0.06	4.5				

continued

Table 9 (continued)

Item	Mail Partial Response Difference Absol.	Rel.	Personal Interview Complete Response Difference Absol.	Rel.	Personal Interview Partial Response Difference Absol.	Rel.	Unobtainable Response Difference Absol.	Rel.	Refused Response Difference Absol.	Rel.
Basins/Sinks	-0.13	-4.9	0.21	8.0	0.12	-4.5				
Toilets	-0.08	-5.2	0.04	2.3	-0.07	-4.5				
Other Taps	-0.38**	-21.5	0.23	13.2	-0.45**	-25.4				
Market Value ($)	-2576*	-12.6	1830	8.9	4636	22.6				
Land Assessment ($)	-62	-3.0	262	12.8	125	6.1	-225*	11.0	-153	7.5
Building Assessment ($)	-438	-9.1	-84	1.8	-13	-0.3	-714*	15.1	-617	13.1
Lot Size (sq. ft.)	-385	-6.1	520	8.2	-179	-2.8	-372°	5.9	77	1.2
Bldg. Area (sq. ft.)	-34	-2.8	27	2.2	137	11.1	-82°	6.7	-48	3.9

continued

Table 9 (continued)

Item	Mail Partial Response		Personal Interview Complete Response		Personal Interview Partial Response		Unobtainable Response		Refused Response	
	Difference		Difference		Difference		Difference		Difference	
	Absol.	Rel.	Absol.	Rel.	Absol.	Rel.	Absol.	Rel.	Absol.	Rel.
AMOUNT PAID FOR WATER ($)										
Winter Bill (Oct. 1967 - April 1968)	-0.39	-1.2	0.27	0.9	1.44	4.6	-0.29	0.9	-1.37	4.4
Summer (May 1968 - Sept. 1968)	-0.27	-1.2	0.20	0.9	1.03	4.6	-0.21	0.9	-0.98	4.4
Annual (Oct. 1967 - Sept. 1968)	-0.66	-1.2	0.47	0.9	2.47	4.6	-0.50	0.9	2.35	4.4

NOTES: See notes bottom of Table 8.

socio-economic level than another subsample also has secondary data of a lower order. For example, home market value of metered customers was estimated by people when interviewed as almost $3,000 less than the estimated value of the mail respondents.[1] Secondary data for these two groups show the personal interview group as having land assessment and building assessment of $291 and $1,127 less than the mail respondents.[1]

Non-responsive Bias

It is often argued that there is no reason why those responding to a survey questionnaire should differ from those not replying. This argument leads to the possible erroneous conclusion that those who did not reply constitute a random sample of the population. As Richmond points out:

> It is not safe to make the assumption that the missing sampling units do not differ from the others because there does not seem to be any reason for such differences with respect to the characteristics being studied.[2]

It may well be that one class of people, such as a particular income class, responds to a certain questionnaire more frequently than the other classes or groups of people that constitute the population studied. Biases of this nature have been known for some time to arise in sample surveys using voluntary mail response questionnaires. The famous Literary Digest Presidential Poll of 1936, which predicted

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[1]Figures are for those people in the complete response sub-sample.

[2]S. Richmond, Statistical Analysis, 2nd ed. (New York: The Ronald Press Co., 1964), p. 329.

the defeat of Franklin Roosevelt, is one of the most noted examples of bias affecting a sample survey. The large error in predicting the results of the election arose from two sources: (1) The sample selection itself did not constitute a true representation of the population; (2) The ballots were returned voluntarily with a high proportion of non-responses. In addition, the ballots returned represented a higher educational and economic level than the non-respondents ballots.[1] Personal interviews were conducted in Calgary at the households that did not respond to the mail questionnaires or the follow-up mail questionnaire to see if there was any bias as a result of using voluntary return mail questionnaires. A comparison of the mail completed returns (i.e. people who answered all questions on the mail questionnaire) and personal interview completed questionnaires (i.e. people who answered all questions when they were interviewed) in Tables 8 and 9 show that the central tendencies of the socio-economic characteristics of the mail respondents and the personal interview respondents differ in some respect. The percentage difference between the means for selected characteristics of mail and personal interview groups as given in Tables 8 and 9 has been summarized in Table 10. It is apparent that the people who were more willing to cooperate in the study (i.e. mail respondents) were generally of higher income classes than those who had to be interviewed in order to obtain a response to the questionnaire.

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[1] Ibid., pp. 328-329.

Table 10

PERCENTAGE DIFFERENCE BETWEEN MEANS OF MAIL RESPONDENTS AND PERSONAL INTERVIEW RESPONDENTS[a] RESIDENTIAL WATER CUSTOMERS CITY OF CALGARY, 1968-1969

Characteristic	Metered Customers	Flat Rate Customers
Persons per household	-11.3	-0.4
Family income	-36.5	-6.9
Market value of home	-14.1	8.9
Land assessment	-13.7	12.8
Building assessment	-21.9	-1.8
Lot size	-12.4	8.2

[a]Using mail respondents as base group.

Another way of showing the bias that arises from a mail survey is to compute the difference between the percent of mail respondents in each characteristic category and the percentage of people who actually fall into that category for the total sample. Shaffer in a food demand study of a residential area has suggested the calculation of the average gross error of the mail surveys to show the magnitude of differences between the mail survey and the total sample.[1] The average gross error is defined as:

> . . . the sum of the differences between the results of the mail survey and the total sample, disregarding the sign, divided by number of categories.[2]

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[1]J. Shaffer, "Estimating Population Characteristics by Mail Survey," <u>Journal of Farm Economics</u>, LXI, No. 4 (November, 1959), 833-837.

[2]<u>Ibid.</u>, 835.

The using of the average gross error of the mail survey is based on the assumption that the total responses, mail plus personal interview, are equivalent to the results that would have been obtained if just personal interviews had been conducted. Based on this assumption, Shaffer has shown that mail surveys result in distributions statistically different (at the 5 percent significance level) from those of the total sample for all characteristics he tested.

Two of the characteristics tested by Shaffer, income and number in household, are of particular interest since these characteristics are also used in the Calgary study. Shaffer found that, while both of these characteristics resulted in the mail survey being statistically different from the total sample, the actual non-response bias (i.e. the difference between the mail and total sample) was quite small as seen in Table 11.

It is important to note that the results of Shaffer's study are not comparable to any results obtained in this study since the class divisions for each characteristic tested by Shaffer are not given. Furthermore, because of weighting bias this method of showing mail response error is unsuitable for this study. Shaffer's findings are important, however, because they do support this study's finding that non-response bias due to the use of voluntary mail questionnaires does exist.

In order to eliminate any bias of means that may exist in the survey because of selective non-response, the unknown variables were estimated. Since data from secondary sources

Table 11

ESTIMATED RESPONSE ERRORS FROM TWO U.S. MAIL SURVEYS[a]

Characteristic	1956 Survey		1954 Survey	
	Average Gross Error of Mail	Largest Error of Mail	Average Gross Error of Mail	Largest Error of Mail
Number in household	1.1	3.2	1.1	1.7
Income	1.9	3.5	1.7	3.8

[a]Based on 1166 mail returns and 937 personal interviews.

Source: J. Shaffer, op. cit., 837.

about each household was available, the use of regression estimates could be used to estimate the unknown variables indirectly. The regression estimate takes the following form:[1]

$x'' = x' + b\,(Y - y')$

Where: x'' = variable to be estimated.

x' = unbiased estimate of x'' from reference group

y' = unbiased estimate of Y from reference group

Y = known variable from group to be estimated

b = regression coefficient of x' on y'

Estimated values for the unknown variables in the unobtainable, refused, and incomplete sub-sample were calculated by the use of the above regression estimate. An example may serve to clarify the procedure used in this model. The

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[1]M. Hansen, et al., Sample Survey Methods and Theory, Vol. I (New York: John Wiley and Sons, 1953), p. 457.

gross family income for the refused response sub-sample of metered customers was estimated in the following manner. Using multiple regression analysis, the equation that best predicted family income for the complete information households (reference group) was determined. The independent variables used in the regression analysis had to be limited to secondary data as only these variables would be available for households in all sub-samples. The equation best determining family income was:[1]

$$I = -868.522 + 4.342A_L + 0.0344\ Q_A$$

Where I = gross family income in dollars

A_L = land assessment of home in dollars

Q_A = gallons of water used per year by the household.

The next step involves taking the values of land assessment and quantity of water consumed for the unknown sub-sample and substituting those values in the above equation. The resulting values of the estimation for income and other variables for metered and flat-rate households are given in Table 2 and Table 3 of Appendix B, respectively. The estimated values for the unknown sub-sample have generally lower values than those given by people responding by mail. These lower values give further support to the finding that lower income class people are more hesitant in replying to the survey questionnaire.

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[1]The coefficient of determination and standard error of estimate for the equation were .554 and $9,349, respectively.

Non-response bias, due to the use of voluntary mail questionnaires, has been shown to exist from the proceeding evidence. If mail questionnaires were used as the only means of obtaining data on household and family characteristics, an overestimation of population characteristics would have occurred due to a greater response by a higher socio-economic class of people than those not responding. However, by including personal interviews with the mail survey returns, the response bias that would have occurred has now been compensated for.

While non-response bias from mail surveys is not desirable, important consideration must be given to the cost of obtaining additional data. A mail survey, while giving a statistically significant different estimation of population characteristics than a personal interview survey, does have a cost advantage over the personal interview method of surveying. The decision about which method to use must be based on a weighting of the accuracy needed against the additional cost of using personal interview surveys.[1]

Combining the Sub-sample

With differences in sub-samples determined, all full-information sub-samples were combined for both metered and flat rate groups. These combined full-information samples allow further analysis to be conducted with fewer number of

[1]For a discussion on cost of mail and personal interview survey methods, see J. Shaffer, *op. cit.*, 833-834.

groups to work with as well as reduce the bias that would have been encountered if only voluntary mail response were used. These samples were then used to form the basis for estimating inter-relationships of variables that exist in Calgary. Table 12 gives the weighted mean values of the combined full information samples for both metered and flat rate customers. However, estimates of variable means are further corrected by using incomplete returns and indirect estimates in order to minimize bias. Table 13 gives a comparison of flat rate and metered customers' different variable means that have been adjusted for non-response bias.

Table 12

COMPARISON OF METERED AND FLAT RATE CUSTOMERS
COMPLETE INFORMATION RETURNS, CITY OF CALGARY
OCTOBER 1967 - SEPTEMBER 1968

Item	Metered Customers	Flate Rate Customers	Difference Absolute[a]	Difference Relative
No. of observations	147	265	--	--
FAMILY CHARACTERISTICS				
No. of Persons				
Mean	3.67	4.07	0.40*	10.9%
S.D.[b]	.13	0.09		
Family Income ($)				
Mean	11,133	10,257	-876	-7.9
S.D.	912	406		
HOUSEHOLD CHARACTERISTICS				
No. of Rooms				
Mean	6.78	6.58	-0.20	-2.9
S.D.	0.16	.11		
Washing Machine				
Mean	0.97	0.98	0.01	1.0
S.D.	0.02	0.01		
Auto. Gar. Disp.				
Mean	0.16	0.17	0.01	6.2
S.D.	0.03	0.02		
Dishwasher				
Mean	0.16	0.18	0.02	12.5
S.D.	0.03	0.02		
Tubs/Showers				
Mean	1.49	1.33	-0.16*	-10.7
S.D.	0.06	0.03		

continued

Table 12 (continued)

Item	Metered Customers	Flat Rate Customers	Difference Absolute[a]	Difference Relative
No. of observations	147	265	--	--
Basins/Sinks				
Mean	3.04	2.68	-0.36**	-11.8
S.D.	0.09	0.06		
Toilets				
Mean	1.71	1.55	-0.16*	-9.4
S.D.	0.06	0.04		
Other Taps				
Mean	2.03	1.78	-0.25**	-12.3
S.D.	0.01	0.004		
Market Value ($)				
Mean	21,629	20,581	-1048	-4.8
S.D.	1,014	617		
Land Assessment ($)				
Mean	2,087	2,065	-21	-1.0
S.D.	98	69		
Building Assessment ($)				
Mean	5,005	4,710	-295	-5.9
S.D.	246	116		
Total Assessment ($)				
Mean	7,092	6,776	-316	-4.4
S.D.	312	157		
Lot Size (sq. ft.)				
Mean	6,195	6,386	191	3.1
S.D.	192	152		
Building Area (sq. ft.)				
Mean	1,310	1,232	-78	-5.9
S.D.	43	26		

continued

Table 12 (continued)

Item	Metered Customers	Flat Rate Customers	Difference Absolute[a]	Difference Relative
No. of observations	147	265	--	--
Lawn Area (sq. ft.)				
Mean	4,885	5,154	269	5.5
S.D.	174	142		
AMOUNT OF WATER USED (GALLONS)				
Annual Total (Oct. 1967 - Sept. 1968)				
Mean	86,347	164,000[c]	86,000	89.9
S.D.	3,491			
AMOUNT PAID FOR WATER ($)				
Winter Billing, $/month (Oct. 1967 - April 1968)				
Mean	3.88	4.45	0.57**	14.8
S.D.	0.10	0.04		
Summer Billing, $/month (May 1968 - Sept. 1968)				
Mean	4.52	4.45	-.07	-1.5
S.D.	0.11	0.04		
Annual Average, $/month (Oct. 1967 - Sept. 1968)				
Mean	4.13	4.45	0.32**	7.7
S.D.	0.10	0.05		

[a]Superscripts indicate probability that samples are drawn from different populations:

**	99%
*	95%
°	90%
No superscript	90%

Student t - test employed according to G. Snedecor, Op. cit., p. 98.

continued

Table 12 (continued)

Footnotes

[b]Standard deviations of population estimates were calculated according to M. Hansen, et al., Op. cit., p. 25.

[c]Estimated Figure - see page 71.

Table 13

COMPARISON OF ADJUSTED SAMPLE MEANS,
METERED AND FLAT RATE CUSTOMERS
CITY OF CALGARY
OCTOBER 1967 - SEPTEMBER 1968

Item	Metered Customers	Flat Rate Customers	Difference Absolute[a]	Difference Relative
No. of observations	292	523	--	--
FAMILY CHARACTERISTICS				
No. of Persons[b]	3.64	3.99	0.35*	9.6%
S.D.[d]	0.29	0.41		
Family Income[b]	$10,834	9,870	-964	-8.9
S.D.	2,377	2,384		
HOUSEHOLD CHARACTERISTICS				
No. of Rooms[b]	6.55	6.38	-0.17	-2.6
S.D.	0.39	0.43		
Washing Machines[b]	0.98	0.98	0.00	0.0
S.D.	0.04	0.05		
Auto. Garbage Disp.[b]	0.17	0.14	-0.03	-17.6
S.D.	0.10	0.12		
Dishwashers[b]	0.16	0.10	-0.06	-37.5
S.D.	0.10	0.16		
Tubs/Showers[b]	1.52	1.32	-0.20*	-13.1
S.D.	0.14	0.14		
Basins/Sinks[b]	3.01	2.62	-0.39**	-12.9
S.D.	0.21	0.22		
Toilets[b]	1.69	1.54	-0.15*	-8.9
S.D.	0.13	0.15		
Other Taps[b]	1.93	1.53	-0.40**	-20.7
S.D.	0.20	0.56		

continued

Table 13 (continued)

Item	Metered Customers	Flat Rate Customers	Difference Absolute[a]	Difference Relative
No. of observations	292	523	--	--
Market Value[b]	$21,710	19,647	-2,063	-9.5
S.D.	2,285	2,322		
Land Assessment[c]	$ 2,071	2,003	-68	-3.3
S.D.	134	108		
Building Assessment[c]	5,066	4,466	-600	-11.8
S.D.	355	221		
Lot Size[c] (sq. ft.)	6,186	6,220	34	0.5
S.D.	284	243		
Building Area[c] (sq. ft.)	1,279	1,215	-64	-5.0
S.D.	66	44		
AMOUNT OF WATER USED (GALLONS)				
Annual Total[c]	$82,106			
S.D.	5,317	n.a.	--	--
AMOUNT PAID FOR WATER ($/MONTH)				
Winter Billing[c] (Oct. 1967 - April 1968)	3.87	4.43	0.56**	14.5
S.D.	0.17	0.07		
Summer Billing[c] (May 1968 - Sept. 1968)	4.41	4.43	0.02	0.4
S.D.	0.19	0.07		

continued

Table 13 (continued)

Item	Metered Customers	Flat Rate Customers	Difference Absolute[a]	Difference Relative
No. of observations	292	523	--	--
Annual Total[c] (Oct. 1967 - Sept. 1968)	4.10	4.43	0.33**	8.0
S.D.	o.14	0.07		

[a]See footnote a, table 12.

[b]Adjusted for non-response bias (see text).

[c]Average of all households sampled.

[d]Standard deviation of population estimate calculated for all variables according to M. Hansen, et al., Op. cit., p. 25.

CHAPTER IV

WATER USE PATTERNS OBSERVED IN CALGARY

Metered Versus Flat Rate Water Consumption

The amount of water going to domestic metered customers is known from billing records kept by Calgary's Consumer Service Department. These records show that the total pumpage to metered customers increased from 906,788,000 gallons in 1965 to 1,329,378,000 gallons in 1968, an increase of 68.2 percent. Consumption per metered service (Table 14) increased from 64,358 gallons per year in 1965 to 90,097 gallons per year in 1968, or 71.4 percent.

While it is impossible to give any exact amounts of water consumption by individual flat rate customers, it is possible to obtain a close approximation of their water use. To estimate water consumption for flat rate users (Table 15), all of the known pumpage (i.e. metered) was added together along with an estimated amount of water allocated for public use (e.g. public buildings, parks) and unaccounted-for water (e.g. losses through leaks). The total amount of water accounted-for was then subtracted from the known total gross pumpage of the system. The residual was taken as the amount of water going to flat rate water customers in the City of Calgary.

The estimated average water use for flat rate customers

Table 14

WATER CONSUMPTION OF METERED HOUSEHOLDS
CITY OF CALGARY, 1965-1968
(Imperial Gallons)

Year[a]	Total Consumption		Consumption Per Metered Service	
	Per Year	Per Month	Per Year	Per Month
1968	1,329,378,000	110,781,500	90,097	7,508
1967	n/a	n/a	n/a	n/a
1966	1,273,216,000	106,101,333	86,396	7,200
1965	906,799,000	75,508,444	64,358	5,363

[a]The metered sample for the water year used in this study, October, 1967, to September, 1968, had a water consumption of 86,347 gallons per service. During this same period Edmonton households were estimated as consuming 64,856 gallons per service.

Source: Calgary, Alberta, Department of Water Works, Annual Report (Calgary: Department of Water Works, 1968).

Table 15

ESTIMATION OF WATER CONSUMPTION BY FLAT RATE CUSTOMERS
CITY OF CALGARY, 1968
(IMPERIAL GALLONS)

TOTAL GROSS PUMPAGE		17,225,660,000
Domestic metered use	1,329,378,000	
Commercial and industrial use	3,467,030,000	
Water sold outside of city limits	160,000,000	
TOTAL WATER ACCOUNTED-FOR	4,956,408,000	
Public and unaccounted-for water, estimate F	2,193,358,000	
Flat rate customers use, estimate F	10,075,894,000	
Estimate S: Public water	344,513,200	
Water unaccounted for	2,584,849,000	
Flat rate customers use, estimate S	9,339,889,800	

Estimate F: 8.3 gallons per capita per day and 8.3 gallons per day each for public and unaccounted-for pumpage. As calculated for North America by G. Fair and J. Geyer, Elements of Water Supply and Waste-Water Disposal (New York: John Wiley and Sons, 1964), p. 24.

Estimate S: 15 percent of gross production assumed to be unaccounted-for, plus 2 percent of gross pumpage for public use.

Source: H. Seidel and Cleasby, *Op. cit.*, 1509.

was calculated and tabulated along with average water use for metered customers in Table 16.[1] It is evident from Table 16 that flat rate households have an average annual water consumption much greater than metered households.

Findings on average water consumption of domestic water users in Calgary (Table 16) correspond to those consumption figures of the American Water Works Association Survey of 1960 as shown in Table 4, Appendix B. The mean residential water consumption of American Water Works Association Survey for all public utilities serving over 10,000 people was approximately 77,000 gallons per house per year.[2] The study, however, had a range of 22,000 gallons to 311,000 gallons per service year.[3]

Average water consumption of residential homes in Calgary may also be compared to the extensive Johns Hopkins Survey (1963-1965), in which the study areas were divided into metered and flat rate pricing areas. The results of

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[1]Of course, gross per capita consumption would be much higher. In 1968 the average per capita consumption, based on total gross pumpage (see p. 71) and an average population of 362,000, was 130 gallons per day. This amount is substantially greater than most cities in Alberta. Edmonton, for example, has a per capita consumption based on total city use of approximately 84 gallons per person per day.

[2]The American Water Works Survey did not distinguish between metered and flat rate homes

[3]Private utilities had a lower mean consumption and a smaller range than public utilities. The mean water consumption for private utilities was 55,000 gallons per service, and the minimum and maximum reported were 27,000 and 199,000 gallons per service per year respectively.

Table 16

WATER CONSUMPTION RATES OF METERED AND FLAT RATE CUSTOMERS
CITY OF CALGARY, 1968
(Imperial Gallons)

Time Period	Per household[a]			Per person[b]		
	Metered	Flat rate		Metered	Flat rate	
		est. F	est. S		est. F	est. S
Per Year	90,097	163,636	151,683	24,752	41,011	38,016
Per Month	7,508	13,636	12,640	2,063	3,417	3,168
Per Day	247	448	416	68	112	104

[a]Calculations based on 14,755 metered households and 61,575 flat rate households.

[b]Calculations based on 3.64 and 3.99 persons per household for metered and flat rate households respectively.

this survey are given in Table 5 of Appendix B. The Hopkins survey found metered households in the Eastern United States used 258 gallons per dwelling per day (compared to Calgary's 247 gallons per dwelling per day), and flat rate households averaged 576 gallons per dwelling per day (compared to Calgary's 448 gallons per dwelling per day).

The findings on average water consumption in Calgary corroborate previous findings that flat rate water consumers do consume substantially more water than do households with meters. However, while the flat rate consumers do use more water than metered water users over the year, their billings

do not reflect this difference. Metered customers who use 7,508 gallons per month pay an average price of $.55 per thousand gallons, while flat rate customers who consume 13,636 gallons pay an average price of only $.33 per thousand gallons.

Comparison of Metered and Flat Rate Characteristics

Most of the items used in assessing flat rates in Calgary (Table 1, Appendix B) are known for the metered and flat rate customers sampled in the study. The information on the assessment items of individual households as well as other information was obtained through household questionnaires and public records (see pp. 14, 15). A household must weigh these items used in assessing flat rates against their expected water use in order to determine which of the two pricing methods would result in the lowest cost per unit of water used. Generally, it would be expected that the more a household had of the factors used in assessing flat rates, the more likely it would be to prefer a metered pricing method.

In order to understand why one household would prefer one method of water pricing and another household another method of pricing, it is necessary to compare family and household characteristics that influence water consumption. For eight of the 13 items used in assessing flat rates in Calgary, survey data is available.[1] Table 17 shows the

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[1]Basins and sinks are listed as two separate items in the city assessment sheet but are combined into one item in the household survey questionnaire.

five items that proved significantly different between metered and flat rate households. In all cases, metered customers had a significantly larger number of assessable items per household than flat rate customers. The other three variables used in assessing flat rates for which there was sample information did not prove to be significantly larger for one group or the other even when tested at the 10 percent significance level.[1]

Table 17

ITEMS OF SIGNIFICANT DIFFERENCE BETWEEN
METERED AND FLAT RATE CUSTOMERS[a]
CITY OF CALGARY
October, 1967 - September, 1968

Item	Assessed Rate Per Item (dollars)	Average Number Per Household: Metered Customers	Average Number Per Household: Flat Rate Customers
Tubs	4.97	1.52	1.32
Toilets	4.62	1.69	1.54
Basins/ Sinks	2.31	3.01	2.62
Additional Taps	1.12	1.93	1.53

[a]5 percent significance level.

Source: Table 13

[1]These variables are the number of rooms in the home, number of dishwashers, and lawn area.

Householders weigh the specific factors used in assessing a rate against the expected bill if a meter were used. A households' expected bill on a metered system is, of course, determined by the amount of water the household used during the billing cycle. The amount of water consumed, as mentioned previously, is a function of both domestic (i.e. indoor use) and outside water use. Since domestic water use does not change much throughout the year and is relatively inelastic with respect to price, most families would base their expected water consumption on their domestic needs. As has been shown in previous studies, the factor that most influences the absolute amount of domestic water use is the number of persons living in the home (see p. 29). The number of people living in the home is not used as an assessment factor in Calgary, hence larger families should prefer a flat rate pricing system. This hypothesis is verified in Table 13, which shows a significantly larger family size for flat rate customers than metered customers, 3.99 for the former and 2.64 for the latter.

Metered Household Water Consumption as Related to Family and Household Characteristics

In order to determine whether findings on family and household characteristics and on patterns of household water use are suggestive of the nature of various demands in residential homes, cross-tabulations of water consumption against family and household characteristics were carried out.[1] It

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[1]For information on the cross-tabulations analysis used here, see N. Nie, et al., Statistical Package for the Social Sciences (Stanford, Calif.: Department of Political Science, Stanford University, January 1, 1969).

was hypothesized that there is a trend toward greater water consumption as the socio-economic level of the household increases.

Households were classified according to water use into five different water classes (Table 18). It is evident from this table that the frequency distribution of households by amount of water used is heavily skewed to the left or towards the lower water use classes. The first water class represents those customers who over the year had a consumption rate no greater than the total amount of water allowed under the monthly minimum charge; this class of minimum water users represents approximately one-quarter of the entire sample. The majority of the consumers used a little more than the 5,000 gallon-per-month minimum allowance but less than 9,000 gallons per month; this group consisted of 47.6 percent of the metered sample. The remaining customers were divided into the remaining three water consumption classes.

Table 18

RATE OF WATER USE CLASSES
METERED CUSTOMERS, CITY OF CALGARY
October, 1967 - September, 1968

Water Class Number	Water Use per Month (Imperial Gallons)	Percent of Sample In Class
1	up to 5,499[a]	25.9
2	5,500 to 8,499	47.6
3	8,500 to 11,499	17.7
4	11,500 to 14,999	3.4
5	14,500 and over	5.4

[a]Total amount of water allowed under monthly minimum charge.

The family characteristics of the number of persons per household and gross family income have been related to the annual rate of water use in Tables 7 and 8 of Appendix B. The results of these cross-tabulations, summarized in Table 19, show that as the family size or the family income increases, the rate of water use also increases. For example, while only approximately 5 percent of the families making less than $10,000 per year were in water classes four or five, 60 percent of the families making over $20,000 were in those two water use classes. Figure 5 may help to demonstrate this finding. The area under each of the five curves represents the total quantity of water taken by the average household of the class. There is a definite increase of water use as the family income level increases. The different levels of water use between income groups is most noticeable during the summer. While all income classes use more water than the average winter consumption (which is represented by the horizontal line), the actual consumption increases as the income level rises.

The relationship of household characteristics to rate of water use is given in Table 20. As the four household characteristics selected increase, the amount of water the city will have to supply will also increase. For example, if an area of the city has homes whose assessed value is less than $5,000 each, the water supply company could expect more than half of these homes to use not more than the 5,000 gallon-per-month minimum allowance. In a more affluent area of the city where homes are assessed over $11,000, the city

Table 19

FAMILY CHARACTERISTICS AND RATE OF WATER USE
METERED CUSTOMERS, CITY OF CALGARY
OCTOBER 1967 - SEPTEMBER 1968
(EACH COLUMN = 100 PERCENT)

Water Class	Number of Persons Per Household			Gross Family Income ($)		
	3 or less	4 to 6	7 or more	up to 9,999	10,000 to 19,999	20,000 and more
1	43.0	10.6	0.0	34.1	18.2	0.0
2 + 3	50.0	81.8	66.7	61.0	76.4	40.0
4 + 5	6.9	7.6	33.3	4.9	5.4	60.0

FIGURE 5

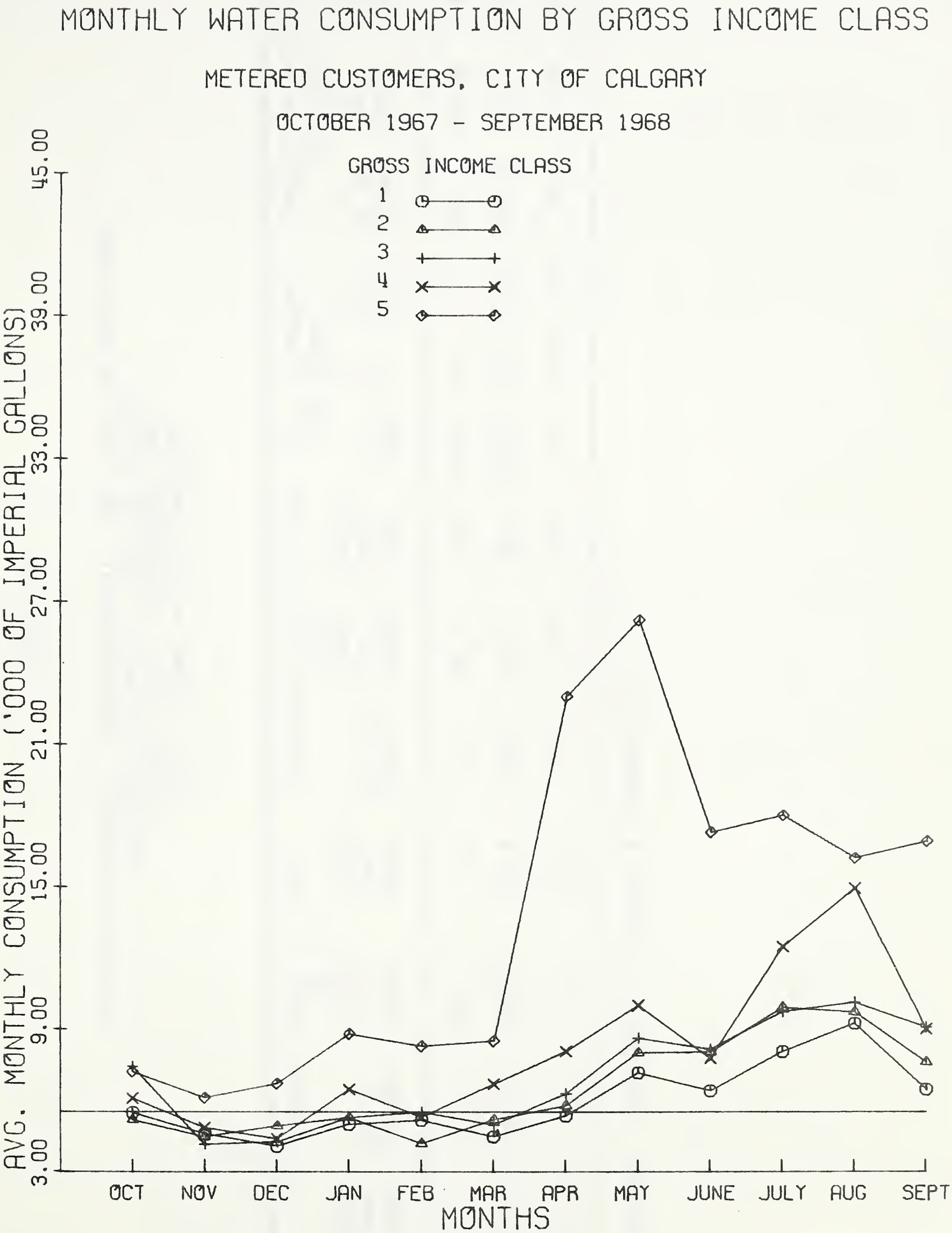
MONTHLY WATER CONSUMPTION BY GROSS INCOME CLASS
METERED CUSTOMERS, CITY OF CALGARY
OCTOBER 1967 - SEPTEMBER 1968
GROSS INCOME CLASS
1
2
3
4
5
AVG. MONTHLY CONSUMPTION ('000 OF IMPERIAL GALLONS)
45.00
39.00
33.00
27.00
21.00
15.00
9.00
3.00
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUNE
JULY
AUG
SEPT
MONTHS

Table 20

SELECTED HOUSEHOLD CHARACTERISTICS AND RATE OF WATER USE, METERED CUSTOMERS, CITY OF CALGARY OCTOBER 1967 - SEPTEMBER 1968 [EACH COLUMN = 100 PERCENT]

Water Use Class	Market Value of Home [$] Up to 10,000	11,000 to 30,000	31,000 and Over	Assessed Value of Home [$] Up to 5,000	5,001 to 11,000	11,001 and Over	No. of Rooms Per Home 4 or Less	5 to 7	8 or More	Lawn Area of Home [sq. ft.] Up to 5,000	5,001 to 9,000	9,001 and Over
1	50.0	27.3	0.0	51.7	20.4	10.0	50.0	32.2	6.7	27.5	25.0	0.0
2 & 3	50.0	67.2	53.8	48.3	74.1	20.0	50.0	62.2	75.5	68.4	63.6	20.0
4 & 5	0.0	5.5	46.2	0.0	5.5	70.0	0.0	5.6	17.8	4.1	11.4	80.0

Source: Appendix 1, Tables 8 through 11.

could expect to deliver an average of 11,000 gallons of water each month to 70 percent of the homes in that area. Figures 6 and 7 show monthly water consumption related to assessment and market value of the home. As in the case when the average monthly water consumption was related to income classes, these two socio-economic characteristics, when related to water consumption, show that as the value of the home increases the amount of water consumed, especially during the summer, also increases.

Peaking

Seasonality

Empirical results here and elsewhere have shown that water utilities serving residential customers have to increase their pumpage substantially during the summer months.[1] Since domestic water use varies little during the year, most of the water pumped in the summer above the average winter pumpage can be attributed to outdoor use, especially lawn sprinkling.[2] Table 21 shows metered households in Calgary have an average summer monthly water consumption rate almost double that of the average winter month. This phenomenon may be accounted for not only by the extra water used in summer lawn sprinkling but also by the reduced summer water rates. (Table 1, Appendix B).

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[1]For example, Linaweaver, et al., op. cit., 272 and H. Afifi, op. cit., , 42.

[2]Howe and Linaweaver, op. cit., 17.

FIGURE 6

MONTHLY WATER CONSUMPTION BY MARKET VALUE CLASS

METERED CUSTOMERS, CITY OF CALGARY

OCTOBER 1967 - SEPTEMBER 1968

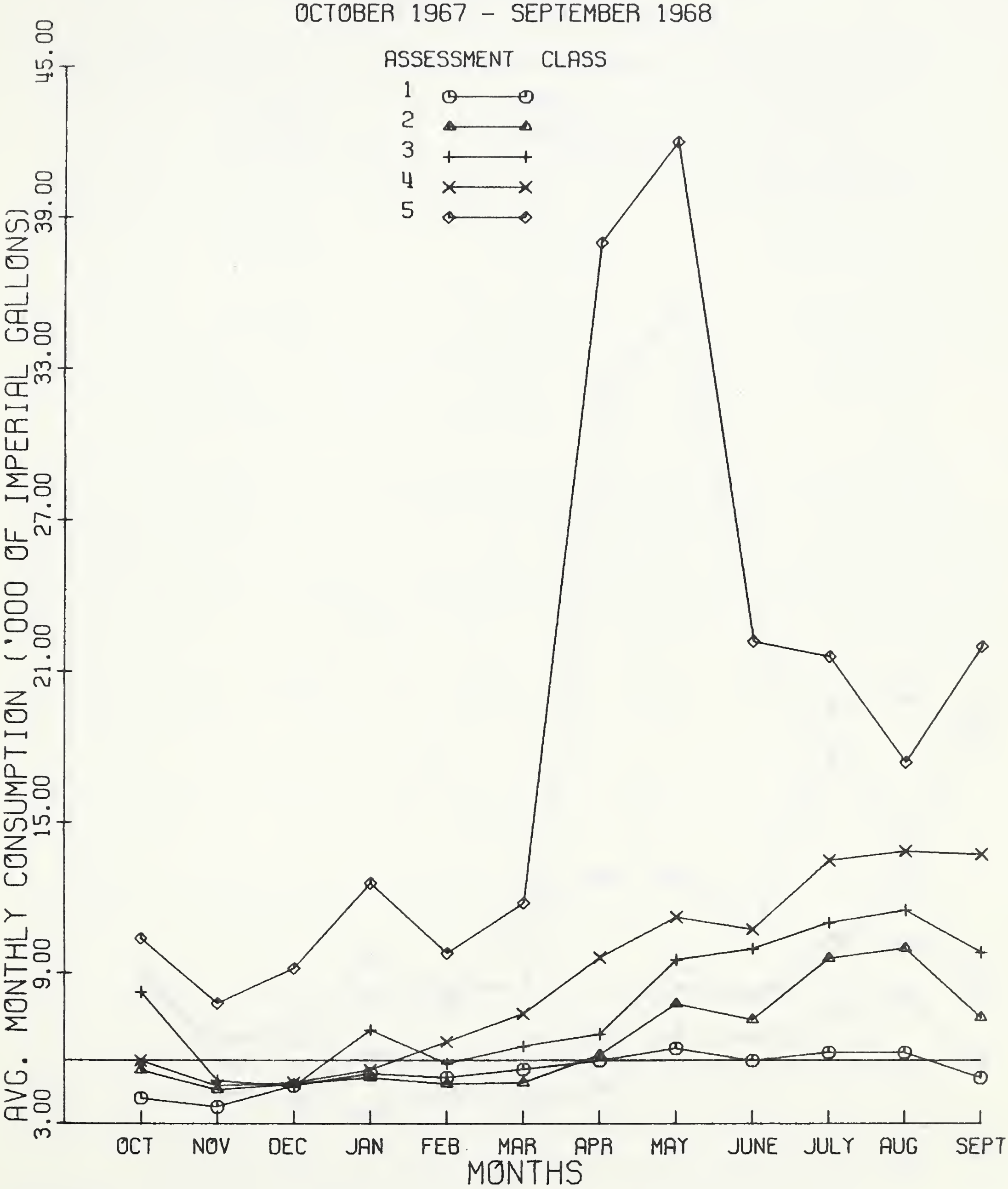


FIGURE 7

MONTHLY WATER CONSUMPTION BY ASSESSMENT CLASS

METERED CUSTOMERS, CITY OF CALGARY

OCTOBER 1967 - SEPTEMBER 1968

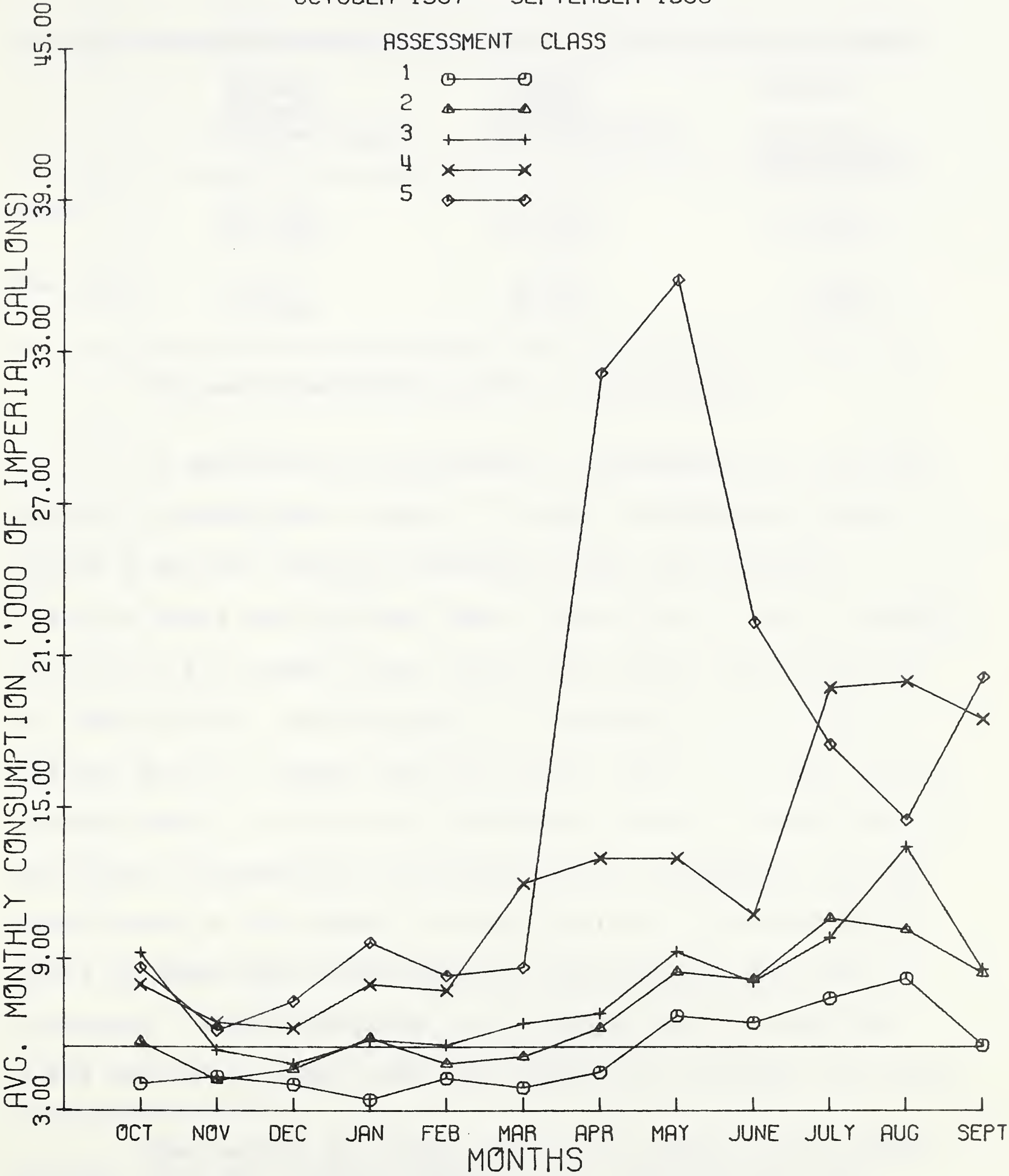


Table 21

SEASONAL WATER CONSUMPTION PER HOUSEHOLD[a]
METERED CUSTOMERS, CITY OF CALGARY
October, 1967 - September, 1968
(Imperial Gallons)

	Winter Season (October-April)	Summer Season (May-September)	Annual (October-September)
TOTAL	38,692 (20,540)	47,733 (25,666)	86,425 (42,022)
Per Month	5,527 (2,934)	9,547 (5,133)	7,202 (3,502)

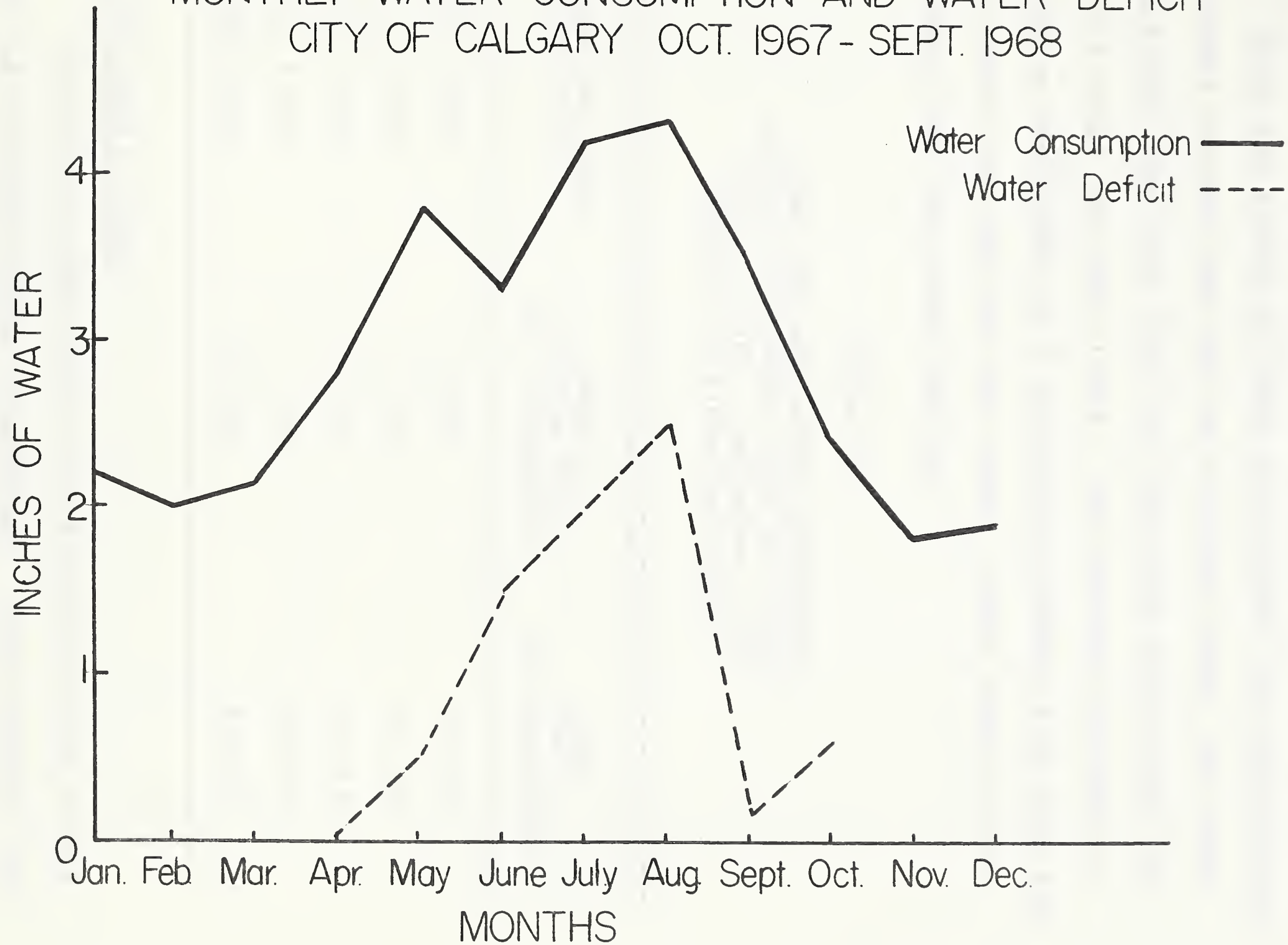
[a]Standard deviations given in parenthesis.

If sprinkling is primarily a consequence of the water deficit as described on page 31, water consumption should follow a pattern directly related to the water deficit. Figure 8 shows that pattern does indeed exist.[1] Water consumption is at its lowest level during the winter when there is no water deficit, and residential consumption is at its highest point in August when the water deficit is also at its highest amount. Letting the difference between households' average winter consumption and maximum month consumption be representative of the amount of water used for lawn sprinkling, Table 22 shows that lawn watering increases as lawn area increases. Households with 3,000 square feet of lawn use 6,495 gallons on their lawn, and homes with between 7,000 and

[1]The months for which there is no point on the water deficit line had a water surplus (i.e. precipitation was greater than evapotranspiration).

Figure 8

MONTHLY WATER CONSUMPTION AND WATER DEFICIT
CITY OF CALGARY OCT. 1967 - SEPT. 1968



9,000 square feet of lawn area use 21,214 gallons on their lawn. While the latter of these two classes has approximately three times as much lawn area as the first class, the homes in the larger lawn area class use more than three times the amount of water for their lawns. The increased sprinkling rate may be attributed to a correlation between lawn area and family wealth and the fact that higher income families use more water than low-income families.

Table 22

LAWN AREA AND WATER CONSUMPTION
METERED CUSTOMERS, CITY OF CALGARY
October, 1967 - September, 1968
(Imperial Gallons Per Month)

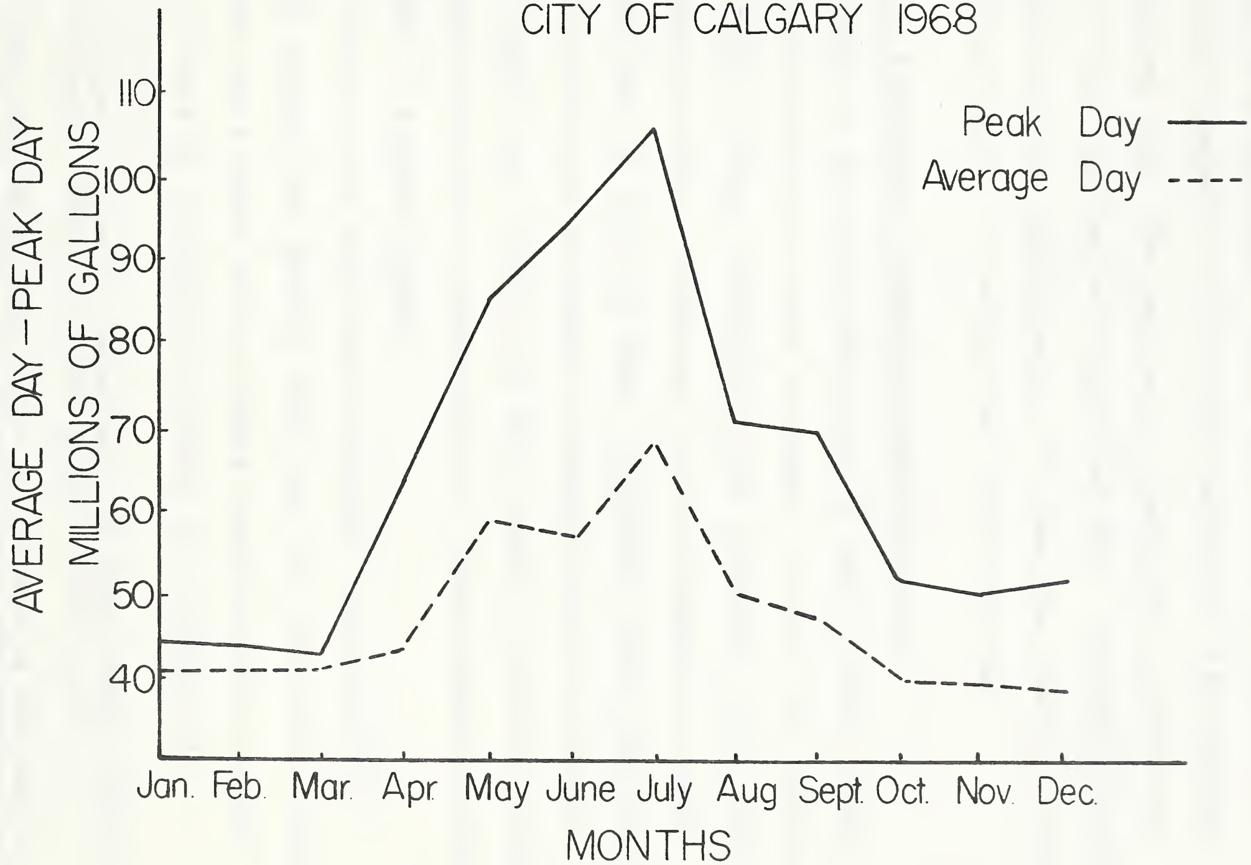
Lawn Area Per Home (square feet)	Winter Average Rate Per Household	High Month Per Household
Up to 3,000	3,238	9,733
3,001 to 5,000	5,353	15,169
5,001 to 7,000	5,540	18,361
7,001 to 9,000	7,536	28,750
9,001 and over	11,600	49,400

Daily and Hourly Peaks

During the summer peak day and peak hour use occurs as well as the peak monthly consumption. Gross pumpage data for Calgary in 1968, Figure 9, shows that the difference between peak day and average day is the greatest during the

Figure 9

AVERAGE AND PEAK DAY WATER CONSUMPTION
CITY OF CALGARY 1968



summer months. The largest peak day in 1968 was in July, when 100,354,000 gallons or 285 gallons per capita per day was consumed in the city. This amount is over twice the average daily pumpage of 47,194,000 gallons or 136 gallons per capita per day. The peak hour consumption in 1968 was reported at 410 gallons per capita per day.[1] The peak hourly consumption rate is approximately 73 times the average hourly consumption rate of 5.6 gallons per capita per day.

Peaking as Related to Household Characteristics

While it has been shown that as family and/or household characteristics increase in number or value the average monthly rate of water consumption also increases, this information does not help in planning for the consumption peaks the system must be built to meet. Although family and household characteristics of metered customers cannot be related to short peaks (e.g. hourly and daily peaks), available information does allow for an examination of these characteristics as related to seasonal peaks.

Table 23 has three socio-economic characteristics tabulated against the maximum water use and the winter average use.[2] The table shows that as these characteristic classes increase, there is a definite increase in a households'

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[1] Calgary, Alberta, Department of Water Works, Annual Report (Calgary: Dept. of Water Works, 1968), p. 2.

[2] The maximum or high month is defined as the sum of each individual households' maximum month's consumption divided by the total number of households in that class.

Table 23

HOUSEHOLD CHARACTERISTICS AND WATER CONSUMPTION
METERED CUSTOMERS, CITY OF CALGARY
OCTOBER 1967 - SEPTEMBER 1968
[IMPERIAL GALLONS PER MONTH]

Characteristic and Class Interval [$]	Persons Per Household	Winter Avg. Rate		High Month	
		Per Person	Per Household	Per Person	Per Household
Total Assessed Value of Home					
Up to 5,000	3.38	1,207	4,079	3,408	11,520
5001 to 8000	3.67	1,429	5,243	4,003	14,690
8001 to 11000	3.50	1,804	6,314	4,971	17,400
11000 to 14000	6.50	1,352	8,786	3,323	21,600
14001 and over	3.67	3,153	11,571	14,986	55,000
Market Value of Home					
Up to 10000	3.83	1,218	4,667	2,133	8,170
11000 to 20000	3.46	1,395	4,827	3,983	14,170
21000 to 30000	3.86	1,561	6,027	4,611	17,800
31000 to 40000	4.62	1,329	6,139	4,654	21,500
41000 and over	4.20	3,388	14,228	13,762	57,800

continued

Table 23 (continued)

Characteristics and Class Interval [$]	Persons Per Household	Winter Avg. Rate		High Month	
		Per Person	Per Household	Per Person	Per Household
Gross Family Income					
Up to 4900	2.82	1,727	4,870	4,172	11,764
5000 to 9900	3.69	1,354	4,995	4,098	15,123
10000 to 14900	3.64	1,487	5,411	4,847	17,643
15000 to 19900	4.53	1,320	5,978	3,871	17,538
20000 and over	3.90	2,519	9,800	9,692	37,800

maximum month consumption as well as their average winter use. Furthermore, the maximum month increases from one socio-economic class to the next at a greater rate than the average winter month's increase. The ratio of average monthly consumption to average maximum monthly consumption increases from approximately 1:2 for the lowest wealth classes of each of the three socio-economic characteristics to a ratio of 1:4 for the highest wealth class. This ratio increase indicates that as the socio-economic level of the home increases, the home not only uses more water but their peak month of consumption is in greater proportion to their average indoor water consumption than people of lower socio-economic levels.

Figures 10, 11, and 12 show the proportional change of water use during the year for these different socio-economic characteristics. The figures have been drawn so that the mean of the average winter use of each individual class is equal to 100. The difference between the average winter use and the individual month's use is then calculated as an index. It is apparent from these figures that as the socio-economic level of the household increases, the variation in water use becomes greater.

Similar results, as when family and household characteristics were related to water use, are obtained when the number of water using appliances and fixtures are related to water use (Table 13, Appendix B). That is, as the number of water using appliances and fixtures increases, the amount of water delivered to a household will increase.

FIGURE 10

MONTHLY WATER CONSUMPTION INDEX BY GROSS INCOME CLASS

METERED CUSTOMERS, CITY OF CALGARY

OCTOBER 1967 - SEPTEMBER 1968

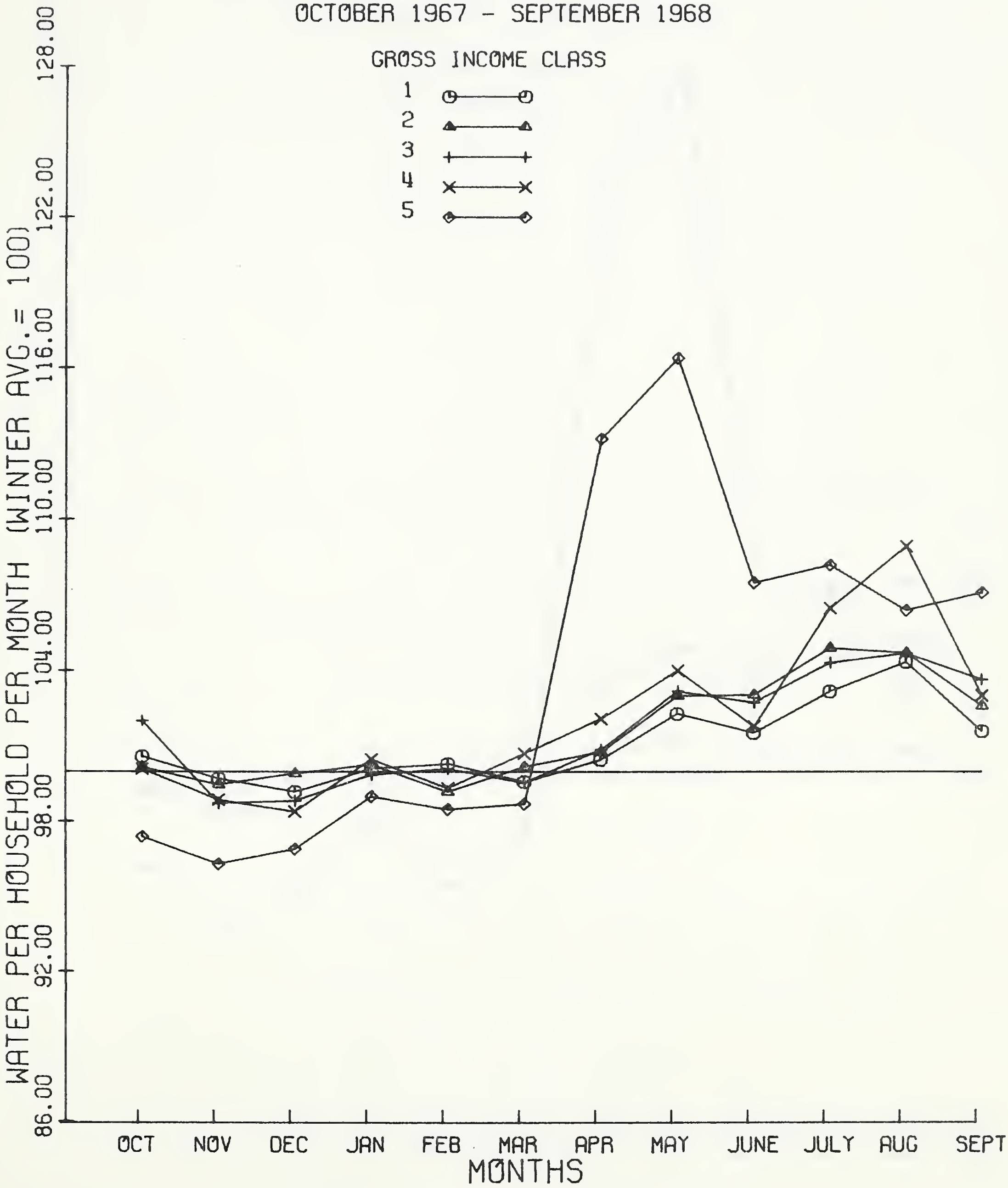


FIGURE 11

MONTHLY WATER CONSUMPTION INDEX BY MARKET VALUE CLASS

METERED CUSTOMERS, CITY OF CALGARY

OCTOBER 1967 - SEPTEMBER 1968

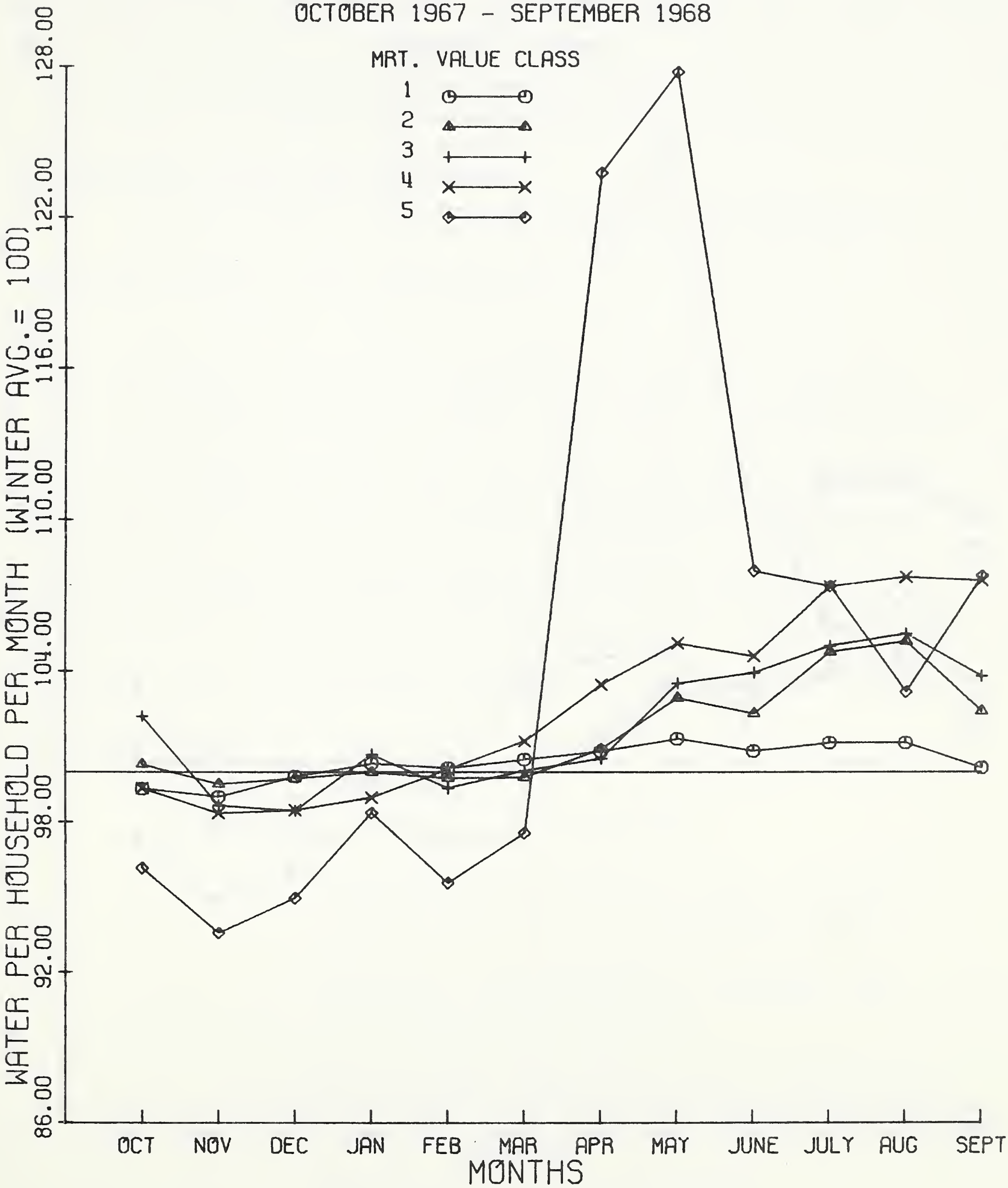
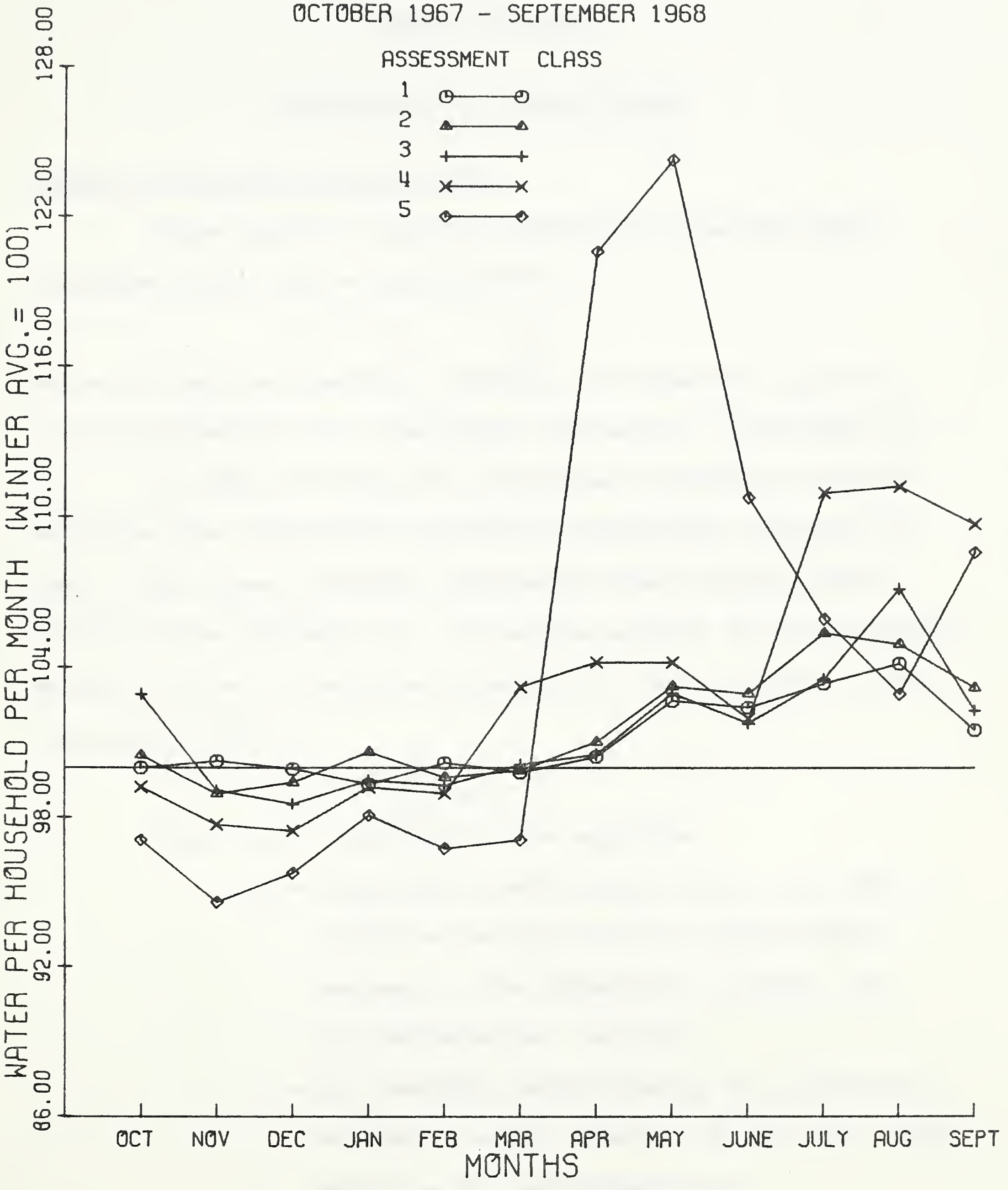


FIGURE 12

MONTHLY WATER CONSUMPTION INDEX BY ASSESSMENT CLASS

METERED CUSTOMERS, CITY OF CALGARY

OCTOBER 1967 - SEPTEMBER 1968



CHAPTER V

DEMAND SHIFTERS

Statistical Estimation Model

General Functional Relationship

There exists a general functional relation among variables which may be expressed as:

$$Y = f\ (X_1\ .\ .\ .\ X_m)$$

Where Y, the one dependent variable, is dependent upon the varying values of the independent variables, X_1 through X_m.

In order to study the functional relations between variables the statistical method of regression analysis is used. The linear multiple regression model assumes additivity of the factors, X_i. It may be written in the following manner to show the expected behavior of the variables in the regression models.

$$Y = a_o + \sum_{i=1}^{m} a_i X_i + U$$

Where a_o = intercept of the equation

a_i = regression coefficients which are used to indicate the statistical relationship between Y, the dependent variable, and X_i the dependent variable.

U = the residual error showing the difference between Y and $\hat{Y}$, where Y is the true value and $\hat{Y}$ is the estimated value.

The non-linear relation assumes a multiplicative relation between variables. It is of the form:

$$Y = b_0 \prod_{i=1}^{m} X_i^{b_i} + V$$

Where b_0 = intercept of the equation

b_i = regression coefficients

V = the residual error

This equation may be converted into a summation of logarithms which renders it amenable to ordinary regression analysis:

$$\text{Log } Y = \text{Log } b_0 + \sum_{i=1}^{m} b_i \log X_i + \log V$$

Multiple-step wise regression and correlation analysis are used in this chapter to determine the empirical relationship between Y (the quantity of water used by the household) and the various independent variables which influence water consumption.[1] The linear model used in this study is estimated by:

$$Y = a_0 + a_1X_1 + a_2X_2 + \ldots + a_iX_n + U/W,P$$

Where the X's may be any of the following:

X_1 = Number of persons in the house

X_2 = Number of rooms in the house

X_3 = Total number of water using appliances (X_5-X_7)

X_4 = Total number of water fixtures (X_8-X_{11})

X_5 = Washing machines

X_6 = Automatic garbage disposal

X_7 = Dishwasher

X_8 = Bathtubs and showers

X_9 = Washbasins and sinks

X_{10} = Toilets

X_{11} = Additional water taps

X_{12} = Market value of the home in hundred of dollars

X_{13} = Gross family income in hundred of dollars

X_{14} = Total assessed value of the home in hundred of dollars[1]

X_{15} = Lot size in hundred of square feet

X_{16} = Lawn area in hundred of square feet

X_{17} = Building assessment in hundred of dollars

W = Water deficit (constant)

P = Price of water (constant)

Statistical Decision Criteria

In order to separate out the share of the variance of the dependent variable associated with the different independent variables, it is necessary first to compute a correlation matrix. A correlation matrix serves two purposes. First, it helps in choosing the variables to be included in the models used in estimating water consumption. The standard partial correlation coefficient, rxy, indicates which variables are most closely associated with water use. For example, the correlation matrix for annual water consumption, Table 24, shows that market value of the home (X_{12}) and lot size of the

[1]Includes the assessed value of both buildings and land.

Table 24

CORRELATION COEFFICIENTS OF ANNUAL WATER
CONSUMPTION AND ASSOCIATED FACTORS
METERED CUSTOMERS, CITY OF CALGARY
OCTOBER 1967 - SEPTEMBER 1968

Variable	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	Y
X_1	1.00	.427	.247	.244	.267	.090	.180	.154	.247	.320	.040	.177	.092	.149	.166	.148	.144	.295
X_2		1.00	.331	.582	.177	.239	.249	.409	.578	.570	.208	.394	.287	.247	.280	.221	.177	.439
X_3			1.00	.477	.391	.775	.802	.331	.391	.489	.238	.455	.304	.397	.335	.298	.432	.403
X_4				1.00	.144	.327	.455	.712	.844	.811	.604	.636	.416	.488	.475	.404	.401	.542
X_5					1.00	-.025	.046	.076	.120	.134	.093	.014	.064	-.022	.025	.011	.053	.148
X_6						1.00	.452	.198	.279	.271	.212	.323	.230	.334	.182	.151	.322	.243
X_7							1.00	.362	.360	.541	.164	.509	.288	.417	.420	.393	.348	.398
X_8								1.00	.548	.648	.148	.483	.271	.334	.369	.282	.257	.425
X_9									1.00	.733	.229	.556	.345	.391	.366	.294	.335	.536
X_{10}										1.00	.181	.682	.417	.539	.496	.412	.449	.566
X_{11}											1.00	.241	.219	.229	.230	.239	.182	.146
X_{12}												1.00	.541	.656	.629	.543	.559	.613
X_{13}													1.00	.494	.487	.454	.407	.429
X_{14}														1.00	.615	.518	.965	.572
X_{15}															1.00	.977	.434	.602
X_{16}																1.00	.337	.538
X_{17}																	1.00	.465
Y																		1.00

home (X_{15}) have the highest standard simple correlation coefficients. A second purpose of the correlation matrix is to show the degree of existing multicollinearity.[1] Table 24 for example, indicates that the correlation between lot size and lawn area of the home is very high, .98. This high correlation means that while these two variables should not be used in the same equation, since it would be impossible to distinguish their separate influences on water consumption, they may be good substitutes for each other. Other variables such as the number of persons in the household (X_1) are not correlated very highly with any other independent variables and thus can be used with any of the other variables without concern for multicollinearity.

Water using appliances (washing machines, automatic garbage disposals and dishwashers) have been grouped together as one variable (X_3), as have the water fixtures (bathtubs and showers, washbasins and sinks, toilets, and additional water taps) been grouped into one variable (X_4). This grouping was done on a priori grounds. Similarity of affect was expected for the variables of similar kind, especially among the water fixtures.

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[1]Johnston defines multicollinearity as:

> . . . the name given to the general problem which arises when some or all of the explanatory variables in a relation are so highly correlated one with another that it becomes difficult, if not impossible, to disentangle their separate influences and obtain a reasonably precise estimate of their relative effect.

J. Johnston, Econometric Methods (New York, McGraw-Hill Book Company, 1963), p. 201.

The statistical equations which best express the relationship between the dependent variable and independent variables were chosen on the following statistical criteria:

(1) Coefficient of Determination of (R^2).

The R^2 value indicates what proportion of the variance in values of the dependent variable can be explained by the independent variables. Since the R^2 is the ratio of associated variation to the total variation in X_1, the greater the value of R^2 the greater the amount of the variance in the dependent variable which is explained by the independent variables.[1]

(2) F-Ratio (F)

In order to test whether sample variances differ more than might be expected on the basis of chance, the sample variances are compared by examining the ratio between them. The result of this test, the F-value, is compared to a table of critical values of F for given degrees of freedom and level of probability to see if the value is statistically significant.[1]

(3) The Standard Error of the Estimate (S_b)

The standard error bears the same relationship to the least squares line as the standard deviation bears to the arithmatic mean. That is, the standard error measures the

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[1]For further discussion see S. Richmond, op. cit., (R^2) 456-458; (F-Ratio) 306-309; (S_b) 433-438; (t) 184-194.

irregularity of the observed points about the line of average relationship. Hence, if all points fell exactly on the line (i.e. Y-values are the same as $\hat{Y}$-values) the standard error would be zero. If there was no relationship between the variables then none of the points would fall on the average line and the standard error would be identical to the standard deviation of the dependent variable.[1]

(4) Student t-Distribution (t)

The value of t, derived by dividing the regression coefficient by its standard error, indicates the level of significance of the individual regression coefficients in an equation. The greater the value of t for an independent variable the greater importance that variable has in estimating the dependent variable.[1]

Method of Model Presentation

In choosing a model for planning not only the statistical attributes of the models must be taken into account but also the availability of the variables which are used must be considered. A model which provides a good statistical estimation would be worthless to planners if the information needed is impossible to obtain. With this in mind, the models used in this chapter are presented in three different ways. The first will include the models which use all available data (i.e. secondary and primary data). The second will include only secondary data and other easily available data (e.g. number of rooms in the home). The third presentation

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[1] *Ibid.*

of the equations will include only those which use secondary data (data which are generated in the course of ordinary municipal administrative activities) as the independent variables.

Annual Domestic Water Consumption

Estimation Using Assessment Variables

Equation (1), Table 25 is the result when the items used in assessing flat rates in Calgary (Appendix B, Table 1) are entered into a step-wise linear regression model. Equation (1) has an explained variation (R^2) of .679 and only two of the variables are significant at the 5 percent probability level. All the calculated regression coefficients had the expected positive algebraic signs except X_{11} (additional water taps).[1]

The average water use allocated to selected assessable items (eq.1) and assessed rate for the items used in assessing flat rates are summarized in Table 26. The rate assessed for an item does not depend upon the amount of water which that item uses. For example, wash basins and sinks which use more water than any other item have one of the lowest assessment rates. This is also true for dishwashers and lawn area of the home which use a great deal of water but have small assessment charges.

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[1]Not too much confidence may be placed in variable X_{11} (additional water taps) since there was a great deal of confusion about what constituted an additional water tap by residents included in the sample survey.

Table 25

SUMMARY OF ESTIMATING EQUATIONS FOR
ANNUAL RESIDENTIAL WATER CONSUMPTION,
CITY OF CALGARY, OCTOBER 1967 - SEPTEMBER 1968

Variable		Coefficient	Sb	Order Variable Entered	F	R^2
(1) $Y = a = bX_2 + bX_7 + bX_8 + bX_9 + bX_{10} + bX_{11} + bX_{16}$						
a	constant	-6.801	31.499[a]	-	18.61	.679
X_2	No. of Rooms	2.971°	1.680	4	-	-
X_7	Dishwashers	7.852	8.448	6	-	-
X_8	Bathtubs/Showers	3.373	5.013	7	-	-
X_9	Basins/Sinks	8.440*	3.531	3	-	-
X_{10}	Toilets	5.998	6.306	1	-	-
X_{11}	Additional Taps	-2.204	2.308	5	-	-
X_{16}	Lawn Area	0.729**	0.138	2	-	-
(2) $Y = a + bX_1 + bX_4 + bX_{14} + bX_{15}$						
a	constant	-11.286	30.337[a]	-	35.55	.700
X_1	No. of People	3.778*	1.561	4	-	-
X_4	All water fixtures	3.640*	1.090	2	-	-
X_{14}	Total assessed value	0.261**	0.086	3	-	-
X_{15}	Lot size	0.568**	0.139	1	-	-
(3) $Y = a + bX_1 + bX_4 + bX_{12} +bX_{15}$						
a	constant	-5.782	30.314[a]	-	35.66	.700
X_1	No. of People	3.810*	1.560	3	-	-
X_4	All water fixtures	2.767**	1.198	4	-	-
X_{12}	Market Value	0.091**	0.030	1	-	-
X_{15}	Lot size	0.575**	0.137	2	-	-
(4) $Y = a + bX_1 + bX_4 + bX_{13} + bX_{15}$						
a	constant	-10.414	31.046[a]	-	32.34	.682
X_1	No. of People	3.898*	1.599	3	-	-
X_4	All water fixtures	4.143**	1.105	2	-	-
X_{13}	Family income	0.041	0.027	4	-	-
X_{15}	Lot size	0.704**	0.132	1	-	-

continued

Table 25 (continued)

Variable		Coefficient	Sb	Order Variable Entered	F	R^2
(5) $Y = a + bX_1 + bX_4 + bX_{12} + bX_{16}$						
a	constant	-1.161	30.711[a]	-	33.83	.691
X_1	No. of People	3.863*	1.580	4	-	-
X_4	All water fixtures	2.985*	1.210	3	-	-
X_{12}	Market Value	0.108**	0.029	1	-	-
X_{16}	Lawn Area	0.520**	0.142	2	-	-
(6) $Y = a + bX_1 + bX_3 + bX_4 + bX_{14} + bX_{15}$						
a	constant	-11.711	30.439[a]	-	28.65	.700
X_1	No. of People	3.542*	1.578	4	-	-
X_3	All water appliances	4.345	4.625	5	-	-
X_4	All water fixtures	3.277**	1.147	2	-	-
X_{14}	Total assessed value	0.246**	0.087	3	-	-
X_{15}	Lot size	0.563**	0.139	1	-	-
(7) $Y = a + bX_2 + bX_5 + bX_6 + bX_7 + bX_8 + bX_9 + bX_{10} + bX_{11} + bX_{16}$						
a	constant	-17.281	31.702[a]	-	14.74	.680
X_2	No. of Rooms	2.590	1.699	4	-	-
X_5	Washing Machines	13.582	10.043	5	-	-
X_6	Auto. Gar. Disp.	5.869	7.975	7	-	-
X_7	Dishwasher	5.350	9.181	9	-	-
X_8	Bathtubs/Showers	3.523	5.010	8	-	-
X_9	Basins/Sinks	8.204*	3.548	3	-	-
X_{10}	Toilets	5.907	6.333	1	-	-
X_{11}	Additional Taps	-2.644	2.334	6	-	-
X_{16}	Lawn Area	0.746**	0.138	2	-	-
(8) $\log Y = a + b \log X_1 + b \log X_4 + b \log X_{14} + b \log X_{15}$						
a	constant	0.438	0.129[a]	-	37.25	.708
X_1	No. of People	0.209**	0.053	2	-	-
X_4	All water fixtures	0.240**	0.083	4	-	-
X_{14}	Total assessed value	0.326**	0.077	3	-	-
X_{15}	Lot size	0.309**	0.094	3	-	-

continued

Table 25 (continued)

Variable		Coefficient	Sb	Order Variable Entered	F	R^2
(9) $\log Y = a + b \log X_1 + b \log X_4 + b \log X_{14} + b \log X_{16}$						
a	constant	0.533	0.129[a]	-	37.24	.708
X_1	No. of People	0.211**	0.053	2	-	-
X_4	All water fixtures	0.251**	0.082	4	-	-
X_{14}	Total assessed value	0.369**	0.071	1	-	-
X_{16}	Lawn Area	0.220**	0.067	3	-	-
(10) $\log Y = a + b \log X_1 + b \log X_4 + b \log X_{12} + b \log X_{15}$						
a	constant	0.242	0.132[a]	-	62.89	.693
X_1	No. of People	0.226**	0.054	3	-	-
X_4	All water fixtures	0.193*	0.092	4	-	-
X_{12}	Market Value	0.249**	0.074	2	-	-
X_{15}	Lot size	0.449**	0.084	1	-	-
(11) $\log Y = a + b \log X_1 + b \log X_4 + b \log X_{13} + b \log X_{15}$						
a	constant	-0.514	0.135[a]	-	34.19	.693
X_1	No. of People	0.206**	0.056	3	-	-
X_4	All water fixtures	0.294**	0.086	2	-	-
X_{13}	Family income	0.089*	0.046	4	-	-
X_{15}	Lot size	0.475**	0.086	1	-	-
(12) $\log Y = a + b \log X_1 + b \log X_2 + b \log X_{14} + b \log X_{15}$						
a	constant	0.366	0.129[a]	-	37.03	.707
X_1	No. of People	0.172**	0.056	2	-	-
X_2	No. of Rooms	0.283**	0.100	4	-	-
X_{14}	Assessed value	0.347**	0.076	1	-	-
X_{15}	Lot size	0.330**	0.094	3	-	-
(13) $Y = a + bX_2 + bX_{14} + bX_{15}$						
a	constant	-14.094	30.082[a]	-	46.74	.699
X_2	No. of Rooms	5.819**	1.338	2	-	-
X_{14}	Assessed value	0.319**	0.083	3	-	-
X_{15}	Lot size	0.623**	0.137	1	-	-

continued

Table 25 (continued)

Variable		Coefficient	Sb	Order Variable Entered	F	R^2
(14) $Y = a + bX_{14} + bX_{15}$						
a	constant	16.549	32.015[a]	-	53.83	.602
X_{14}	Assessed value	0.356**	0.088	2	-	-
X_{15}	Lot size	0.719**	0.143	1	-	-
(15) $\log Y = a + b \log X_{14} + b \log X_{15}$						
a	constant	-1.163	0.139[a]	-	51.25	.642
X_{14}	Assessed value	0.427**	0.080	1	-	-
X_{15}	Lot size	0.380**	0.101	2	-	-

a = standard error of the estimate
° = significant at .10 probability level
* = significant at .05 probability level
** = significant at .10 probability level

Table 26

AVERAGE WATER USE AND ASSESSED RATE FOR ASSESSMENT ITEMS
CITY OF CALGARY
October, 1967 - September, 1968

Item	Average Water Use (Gallons)	95 percent Confidence Interval (Gallons)	Assessed Rate ($)
Rooms (X_2)	2,971	0-6,264	7.19[a]
Dishwasher (X_7)	7,852	0-24,410	2.31
Bathtubs/ Showers (X_8)	3,373	0-13,198	4.97
Basins/ Sinks (X_9)	8,440	1,519-15,361	2.31
Toilets (X_{10})	5,998	0-18,358	4.62
Lawn area (X_{16}) (Per 1000 sq. ft.)	7,289	4,592-9,986	0.63

[a]minimum rate per room for the first three rooms. The rate per room decreases as the number of rooms increase, Appendix B, Table 1. For example, the rate per room for a house with six rooms is $4.36.

Estimation Using all Available Data

Employing all the data obtained from primary and secondary sources, various regression estimates by annual water use were obtained. The linear equation which best estimates annual water consumption of metered customers in Calgary is:

$$(2)\ Y = -11.286 + 3.778X_1 + 3.640X_4 + 0.261X_{14} + 0.568X_{15}$$

The above equation may be interpreted in the following manner. Households will increase their annual water consumption by

3,778 gallons for every additional person living in the home, by 3,640 for every new water fixture placed in the home (e.g. bathtubs, showers, basins, or toilets), by 261 gallons for every one hundred dollars increase in assessed value of the home and by 568 gallons for every additional one hundred square feet of lot size. Table 25 shows that all the variables in the equation are significant at the 5 percent probability level and the equation has a coefficient of determination of 0.700 (i.e. 70 percent of the variation in the dependent variable is explained by the independent variables). All the calculated regression coefficients had the expected algebraic signs.

Similar statistical results (e.g. S_b, t, R^2, F) are obtained when market value of the home (as estimated by residents) is used instead of assessed value of the home, equation (3). However, since assessed value is more readily available than market value, equation (2) is preferable for practical use. Gross family income was also tried in place of assessed value and market value of the home, equation (4). The statistical results obtained from using family income instead of assessed value or market value are not as good. It appears that the value of homes is a better estimator of water consumption than family income (see also North).[1]

Lot size (X_{15}) proved to give better statistical estimation of water use than lawn area (X_{16}) in all linear models tried. For example, in equation (5) when lawn area is

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[1]R. North, *op. cit.*, p. 8.

substituted for lot size slightly poorer statistical results than in equation (3) were obtained. Lot size not only provides better statistical results but also has the advantages of being more easily obtainable than lawn area.

If water appliances (washing machines, garbage disposals, and dishwashers) are entered into a regression model along with assessed value of the home, number of persons in the household, and lot size of the home, it develops that water using appliances are not a significant variable in that particular model, equation (6). That is, no improvement over equation (2) which omits X_3 (water using appliances) is found by adding X_3 to that equation.

In order to evaluate the affect of washing machines (X_5) and automatic garbage disposals (X_6) which are not used in assessing flat rates in Calgary, X_5 and X_6 have been added to equation (1). It appears from equation (7) that especially washing machines are as an important factor as any other appliance or fixture to be considered when assessing flat rates.

To test for nonlinearity in the independent variables with respect to annual water consumption various logarithmic equations were estimated. The non-linear equations which best estimates annual water consumption is:

(8) $\log Y = 0.438 + 0.209X_1 + 0.240X_4 + 0.326X_{14} + 0.309X_{15}$

The equation, which is equation (2) in non-linear form, has an explained variation of .708 and all the variables are significant at the 1 percent probability level. Substituting lawn area (X_{16}) for lot size (X_{15}) has little effect on the

statistical results of the logarithmic equations, equation (9).

Gross family income and market value of the home were also tried in place of assessed value in non-linear equations. The statistical results as given in equation (10) and (11) however, are not as good as when assessed value is used as an independent variable.

Estimation Using Easily Available Data

When the independent variables are limited to just secondary data (p. 37) and other easily available data (i.e. number of rooms, and number of persons living in the house) the equation which best estimates annual water consumption is:

(12) $\text{Log } Y = 0.366 + 0.172X_1 + 0.283X_2 + 0.347X_{14} + 0.330X_{15}$

Equation (12) has an explained variation of .707 and all the variables are significant at the 1 percent probability level. This equation gives approximately the same statistical results as the best non-linear equation using all available data, equation (8). The only difference between the variables in equation (8) and (12) is that equation (12) uses number of rooms in place of all water fixtures.

As in the case when all available data is considered for use as independent variables, the linear model does not give quite as good results as the logarithmic model when only secondary and other easily available data is employed. The linear model which gives the best estimation of annual water use using secondary and other easily available data is:

(13) $Y = -14.095 + 5.819X_2 + 0.319X_{14} + 0.623X_{15}$

Equation (13) has an explained variation of .699 and all the

variables are significant at the 1 percent level probability level. This equation gives about the same statistical results as equation (2), the best linear model using all data, and has the advantage of using fewer and more readily available data.

Estimation Using Secondary Data

Because of the problem of obtaining data it is desirable to obtain the equation which best estimates water consumption from secondary data only. Using the secondary data listed on page 37, the linear equation which best estimates annual water consumption is:

(14) $Y = 16.549 + 0.356X_{14} + 0.719X_{15}$

Both assessed value of the home (X_{14}) and lot size (X_{15}) have regression coefficients that are significant at the 1 percent probability level. The explained variation is now .602. By eliminating the number of persons in the household and the number of water fixtures from equation (2) the explained variance is reduced by approximately 10 percentage points.

The non-linear equation which best estimates annual water use when only secondary data is considered is:

(15) $\text{Log } Y = -1.163 + 0.427X_{14} + 0.380X_{15}$

Both assessed value (X_{14}) and lot size (X_{15}) have regression coefficients which are significant at the 1 percent probability level. The explained variation is .642 which is 4 percentage points better than the same equation in linear form, equation (14).

Winter Domestic Water Consumption

Because of the seasonal variation in water use by residential customers, predictive models of seasonal water consumption should prove more useful than a model which is determined by annual water use.

Estimation Using Assessment Variables

The variables used in assessing flat rates in Calgary are entered into a step-wise multiple regression model for the winter season in equation 16 (Table 27). Equation (16) has an explained variation of .549 and only two of the independent variables in the model are significant at the 5 percent probability level. All the calculated regression coefficients had the expected algebraic signs with the exception of X_{11} (additional water taps). Equation (16) has an explained variation 13 percentage points less than the same equation for the entire year, equation (1).

Best Estimate Using all Available Data

The linear equation using all available data which best estimates winter water consumption is:

(17) $Y = 0.467 + 1.888X_1 + 1.243X_3 + 0.156X_{14} + 0.206X_{16}$

Equation (17) has an explained variation of .584 and all the variables are significant at the 5 percent probability level. The importance of lawn area (X_{16}) in the equation may be explained in part by the correlation of lawn area to the value of the home.

When lot size (X_{15}) is substituted for lawn area (X_{16}) in equation (18) the explained variation is increased slightly

Table 27

SUMMARY OF ESTIMATING EQUATIONS FOR
WINTER RESIDENTIAL WATER CONSUMPTION
CITY OF CALGARY, OCTOBER 1967 - APRIL 1968

Variable		Coefficient	Sb	Order Variable Entered	F	R^2
(16)	$Y = a + bX_2 + bX_7 + bX_8 + bX_9 + bX_{10} + bX_{11} + bX_{16}$					
a	constant	2.044	17.556[a]	-	9.80	.549
X_2	No. of Rooms	0.896	0.936	4	-	-
X_7	Dishwashers	2.444	4.708	6	-	-
X_8	Bathtubs/Showers	5.538*	2.794	2	-	-
X_9	Basins/Sinks	2.438	1.968	3	-	-
X_{10}	Toilets	1.044	3.515	7	-	-
X_{11}	Additional Taps	-1.336	1.286	5	-	-
X_{16}	Lawn area	0.317**	0.077	1	-	-
(17)	$Y = a + bX_1 + bX_3 + bX_{14} + bX_{16}$					
a	constant	0.467	16.879[a]	-	19.47	.584
X_1	No. of People	1.888*	0.868	3	-	-
X_4	All water fixtures	1.243*	0.599	4	-	-
X_{14}	Assessed value	0.156**	0.045	1	-	-
X_{16}	Lawn area	0.206**	0.078	2	-	-
(18)	$Y = a + bX_1 + bX_4 + bX_{14} + bX_{15}$					
a	constant	-1.121	16.744[a]	-	20.36	.593
X_1	No. of People	1.861*	0.862	3	-	-
X_4	All water fixtures	1.103°	0.601	4	-	-
X_{14}	Assessed value	0.131**	0.048	2	-	-
X_{15}	Lot size	0.236**	0.077	1	-	-
(19)	$\log Y = a + b \log X_1 + b \log X_3 + b \log X_{14}$					
a	constant	0.392	0.157[a]	-	30.58	.618
X_1	No. of People	0.277**	0.064	2	-	-
X_4	All water fixtures	0.169°	0.100	3	-	-
X_{14}	Assessed value	0.472**	0.080	1	-	-

continued

Table 27 (continued)

Variable		Coefficient	Sb	Order Variable Entered	F	R^2
(20)	$\log Y = a + b \log X_1 + b \log X_4 + b \log X_{14} + b \log X_{15}$					
a	constant	0.108	0.153[a]	-	26.19	.642
X_1	No. of People	0.263**	0.063	2	-	-
X_4	All water fixtures	0.137**	0.099	4	-	-
X_{14}	Assessed value	0.333	0.092	1	-	-
X_{15}	Lot size	0.322**	0.112	3	-	-
(21)	$\log Y = a + b \log X_1 + b \log X_{14} + b \log X_{15}$					
a	constant	0.127	0.153[a]	-	34.05	.639
X_1	No. of People	0.275**	0.062	2	-	-
X_{14}	Assessed value	0.370**	0.088	1	-	-
X_{15}	Lot size	0.340**	0.111	3	-	-
(22)	$\log Y = a + b \log X_2 + b \log X_{14} + b \log X_{15}$					
a	constant	0.008	0.160[a]	-	27.75	.599
X_2	No. of Rooms	0.304**	0.116	3	-	-
X_{14}	Assessed value	0.353**	0.094	1	-	-
X_{15}	Lot size	0.366**	0.116	2	-	-
(23)	$Y = a + bX_1 + bX_2 + bX_{14} + bX_{15}$					
a	constant	-2.087	16.783[a]	-	20.11	.590
X_1	No. of People	1.542°	0.926	3	-	-
X_2	No. of Rooms	1.323°	0.806	4	-	-
X_{14}	Assessed value	0.149**	0.046	2	-	-
X_{15}	Lot size	0.252**	0.075	1	-	-
(24)	$Y = a + bX_2 + bX_{14} + bX_{15}$					
a	constant	-0.418	16.827[a]	-	16.83	.583
X_2	No. of Rooms	1.858*	0.743	3	-	-
X_{14}	Assessed valued	0.150**	0.046	2	-	-
X_{15}	Lot size	0.256**	0.076	1	-	-
(25)	$\log Y = a + b \log X_{15} + b \log X_{17}$					
a	constant	-1.467	0.161[a]	-	37.97	.584
X_{15}	Lot size	0.468**	0.107	2	-	-
X_{17}	Bldg. Assessment	0.340**	.073	1	-	-

continued

Table 27 (continued)

Variable		Coefficient	Sb	Order Variable Entered	F	R^2
(26)	$Y = a + bX_{14} + bX_{15}$					
a	constant	9.371	17.084[a]	-	33.83	.561
X_{14}	Assessed value	0.162**	0.047	1	-	-
X_{15}	Lot size	0.286**	0.076	2	-	-

a = standard error of the estimate
° = significant at .10 probability level
* = significant at .05 probability level
** = significant at .01 probability level

to .593 but only three of the independent variables in this equation are significant at the 5 percent probability level.

One non-linear equation which estimates winter water use is:

(19) $\text{Log } Y = 0.392 + 0.277X_1 + 0.169X_3 + 0.472X_{14}$

This equation has an explained variation of .618 and X_1 and X_{14} are significant at the 5 percent probability level. All water fixtures (X_3) is significant at the 10 percent probability level. If lot size is added to equation (19) the explained variation increases to .642. However, variable X_3 is not significant even at the 10 percent probability level, equation (20).

Estimation Using Easily Available Data

Using data which may be easily obtained, the equation which best estimates winter water consumption of households is:

(21) $\text{Log } Y = 0.127 + 0.275X_1 + 0.370X_{14} + 0.340X_{16}$

Equation (21) has an explained variation of .639 and all variables are significant at the 1 percent probability level. Equation (21) does in fact give a better estimation than linear equation (18) which uses all available data. If the number of rooms in the household (X_2) is substituted for number of people (X_1) in equation (21), the explained variation drops to .599, equation (22).

The linear model using the easily available data also produced good statistical results. The linear model which best estimates winter water use is:

(23) $Y = 2.087 + 1.542X_1 + 1.323X_2 + 0.149X_{.4} + 0.252X_{15}$

This linear equation has an explained variation of .590 and two of the variables (X_{14}, X_{15}) are significant at the 1 percent probability level and the other two variables are significant at the 10 percent probability level. If the number of people (X_1) is dropped from equation (23) the explained variation is now .583 and all variables are significant at the 5 percent probability level, see equation (24). The statistical results of equation (24) are not as good as when this equation was used in estimating annual water use (see equation (13)).

Estimation Using Secondary Data

When only secondary data is considered for use as the independent variables the equation which best estimates winter water use is:

(25) $\text{Log } Y = -1.467 + 0.468X_{15} + 0.340X_{17}$

Equation (25) has an explained variation of .584 and both lot size (X_{15}) and building assessment (X_{17}) are significant at the 1 percent probability level.

The linear model which best explains winter water use when only secondary data is considered is:

(26) $Y = 9.371 + 0.162X_{14} + 0.286X_{15}$

The explained variation of the linear equation is .561 and both assessed value of the home (X_{14}) and lot size (X_{15}) are significant at the 1 percent probability level.

Summer Domestic Water Consumption

Estimation Using Assessment Variables

When the variables used in assessing flat rates in Calgary are entered into a regression equation for estimating summer water consumption equation (27), Table 28 is the result. Equation (27) has an explained variation of .678 and three of the variables, X_2, X_9, and X_{16}, are significant at the 5 percent probability level. All the calculated regression coefficients had the expected algebraic signs except for bathtubs and showers (X_8) and additional taps (X_{11}). With the exception of the negative sign for bathtubs and showers, equation (27) gives as good a statistical estimation for summer water use as equation (1) did for annual water use.

Estimation Using All Available Data

The linear model which best estimates summer water consumption is:

(28) $Y = -6.641 + 1.931X_1 + 1.930X_4 + 0.054X_{12} + 0.318X_{15}$

Equation (28) has an explained variation of .677 and all the variables are significant at the 5 percent probability level. The explained variation will decrease only to .670 when assessed value (X_{14}) is substituted for market value (X_{12}), equation (29). Equation (29) while giving an estimation of summer water use better than the same equation for estimating winter consumption (equation (18)), does not give quite as good an estimation as when used in estimating annual consumption, equation (2).

The best logarithmic model for predicting water

Table 28

SUMMARY OF VARIABLES AFFECTING
SUMMER RESIDENTIAL WATER CONSUMPTION
CITY OF CALGARY, MAY 1968 - SEPTEMBER 1968

Variable		Coefficient	Sb	Order Variable Entered	F	R^2
(27)	$Y = a + bX_2 + bX_7 + bX_8 + bX_9 + bX_{10} + bX_{11} + bX_{16}$					
a	constant	-8.845	19.275[a]	-	18.44	.678
X_2	No. of Rooms	2.075*	1.028	4	-	-
X_7	Dishwashers	5.408	5.169	5	-	-
X_8	Bathtubs/Showers	-2.165	3.607	6	-	-
X_9	Basins/Sinks	6.002**	2.161	3	-	-
X_{10}	Toilets	4.954	3.859	1	-	-
X_{11}	Additional Taps	-0.868	1.412	7	-	-
X_{16}	Lawn Area	0.412**	0.084	2	-	-
(28)	$Y = a + bX_1 + bX_4 + bX_{12} + bX_{15}$					
a	constant	-6.641	19.082[a]	-	31.46	.677
X_1	No. of People	1.931*	0.982	4	-	-
X_4	All water fixtures	1.930*	0.754	3	-	-
X_{12}	Market Value	0.054**	0.019	1	-	-
X_{15}	Lot size	0.318**	0.086	2	-	-
(29)	$Y = a + bX_1 + bX_4 + bX_{14} + bX_{15}$					
a	constant	-10.125	19.258[a]	-	30.24	.670
X_1	No. of People	1.915**	0.991	4	-	-
X_4	All water fixtures	2.537**	0.692	2	-	-
X_{14}	Assessed value	0.130**	0.055	3	-	-
X_{15}	Lot size	0.333**	0.088	1	-	-
(30)	$\log Y = a + b \log X_1 + b \log X_4 + b \log X_{14} + b \log X_{15}$					
a	constant	0.154	0.152[a]	-	27.88	.654
X_1	No. of People	0.172**	0.062	3	-	-
X_4	All water fixtures	0.333**	0.098	2	-	-
X_{14}	Assessed value	0.327**	0.091	1	-	-
X_{15}	Lot size	0.282**	0.111	4	-	-

continued

Table 28 (continued)

Variable		Coefficient	Sb	Order Variable Entered	F	R^2
(31) $Y = a + bX_2 + bX_{14} + bX_{15}$						
a	constant	-13.677	19.028[a]	-	41.49	.677
X_2	No. of Rooms	3.961**	0.841	2	-	-
X_{14}	Assessed value	0.169**	0.052	3	-	-
X_{15}	Lot size	0.367**	0.086	1	-	-
(32) $Y = a + bX_{14} + bX_{15}$						
a	constant	7.179	20.311[a]	-	44.57	.615
X_{14}	Assessed value	0.194**	0.056	2	-	-
X_{15}	Lot size	0.433**	0.091	1	-	-

a = standard error of the estimate
° = significant at .10 probability level
* = significant at .05 probability level
** = significant at .01 probability level

consumption during the summer is:

(30) $\text{Log } Y = 0.154 + 0.172X_1 + 0.333X_4 + 0.327X_{14} + 0.282X_{15}$

This non-linear equation has an explained variation of .654 and all the variables are significant at the 1 percent probability level.

Estimation Using Easily Available Data

Using easily available data the equation which best estimates summer residential water consumption is:

(31) $Y = -13.677 + 3.961X_2 + 0.169X_{14} + 0.367X_{15}$

This equation has an explained variation of .667 and all the variables are significant at the 1 percent probability level. Equation (31) gives then an estimation of summer water consumption as good as equation (28) when both secondary and primary data were used in the estimation model.

Estimation Using Secondary Data

Restricting the independent variables to just available secondary data the equation which best estimates the summer water use is:

(32) $Y = 7.179 + 0.194X_{14} + 0.433X_{15}$

Both assessed value of the home (X_{14}) and lot size (X_{15}) are significant at the 1 percent probability level. The equation has a coefficient of determination of .615. The explained variation of equation (32) is .063 percentage points less than the similar equation with the number of rooms, equation (31). Equation (32) however does give an explained variation greater than similar equations for either winter or annual water use estimation, see equations (14) and (26).

Elasticity

The elasticity of a variable with respect to the amount of water used may be measured at the mean by the formula $\frac{\bar{x}}{\bar{y}}$ (β_g) where $\bar{y}$ is the mean dependent variable and $\bar{x}$ is the mean of the independent variable and β_g is the regression coefficient for that particular variable. Any estimation of income elasticity should be done by eliminating all independent variables except income from the estimating equation since these other variables are also a function of income.[1] So as to avoid any specification error, simple two-variable regressions of income (or one of its proxy variables), or family size as the determinant of annual residential water use were calculated, equations 33 through 36, Table 29. The coefficients obtained from these equations reflect the direct differences in family wealth or family size. The income elasticity of + .207 computed for Calgary is much lower than other comparable findings such as North's +0.83 (see Table 1).

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[1]It would be appropriate to obtain an approximation of income elasticity of components (e.g. lot size) in an equation by adding their elasticities. This estimate would only hold true however, when there is equi-proportionate expansion of all factors in the equation.

Table 29

SUMMARY OF EQUATIONS USED IN
ESTIMATING ELASTICITY COEFFICIENTS
CITY OF CALGARY, OCTOBER 1967 - SEPTEMBER 1968

Variable		Coefficient	Sb	F	R^2	Elasticity
(33)	$Y = a + bX_1$					
a	constant	58.819	40.166[a]	13.79	.295	.318
X_1	No. of People	7.508**	2.022	-	-	-
(34)	$Y = a + bX_{13}$					
a	constant	68.420	37.973[a]	32.66	.429	.207
X_{13}	Family income	0.161**	0.028	-	-	-
(35)	$Y = a + bX_{12}$					
a	constant	41.543	32.204[a]	87.36	.613	.518
X_{12}	Market Value	0.207**	0.022	-	-	-
(36)	$Y = a + bX_{14}$					
a	constant	41.814	34.480[a]	70.47	.572	.493
X_{14}	Assessed Value	0.628**	0.075	-	-	-

a = standard error of the estimate
° = significant at .10 probability level
* = significant at .05 probability level
** = significant at .01 probability level

CHAPTER VI

SUMMARY AND IMPLICATIONS

Summary

Survey Bias

The procedure used in gathering data for this study offered an opportunity to determine to what extent, if any, the use of mail questionnaires biased the estimation of population characteristics. A definite lack of response to the mail questionnaire by lower income families was found to exist by analyzing mail responses against (1) the information obtained from personal interviews of the homes which did not reply to the mail questionnaire and (2) the secondary information obtained from public records for all homes in the study. If the non-response bias in the mail survey had not been accounted for, it would have caused an over estimation of the family and household characteristics for the population.

The two questions people were most hesitant in answering in the survey were those pertaining to their income and the value of their home. This reluctance was due, in part, to the lack of understanding of these questions' importance to the study. It was also found that the personal interview group had a significantly larger number of people refusing to answer these two questions than the mail response group.

Metered and Flat Rate Water Usage

By obtaining information on metered customers and allocating a certain amount of water for public use and water losses (e.g. leaks), an estimation of water use by flat rate customers was obtained. It was estimated that homes on flat rates used about 160,000 gallons of water per year. Metered customers, however, used only 86,000 gallons of water during the year. While flat rate customers used nearly twice the amount of water as metered customers, the average revenue collected was approximately the same from both customers, $51.95 for the former and $52.00 for the latter.

In order to find out why a household prefers one method of pricing to the other, a comparison of metered and flat rate households against the items used in assessing flat rates was performed. There was found to be a definite relationship between the number of assessment items in a home and the pricing method that home chose. That is, people weigh the number of assessment items in their home (i.e. flat rate) against their expected water consumption in order to decide which pricing method will result in the lowest cost per unit of water used. Households with a large number of assessment items showed preference for metering while those homes with a smaller number of assessment items preferred a flat rate.

It was also observed that the number of people living in a home, which is not used in assessing flat rates, also influenced the choosing of a household's water pricing method. Households with large families were found to show preference

for flat rate pricing while homes with small families preferred metering.

Water Use Patterns

The seasonal water use patterns observed for households in Calgary showed that metered customers used a great deal more water during the summer than the winter. The average monthly consumption increased from approximately 5,500 gallons per month in the winter to 9,500 gallons per month in the summer. This increase may be attributed not only to increase water use due to lawn sprinkling, but also to the lower water rates for metered customers which exist in the summer.

The amount of water needed for lawn sprinkling was found to be directly related to the lawn area of the home and the existing water deficit (i.e. precipitation minus evapotranspiration). During the summer months when the water deficit was small, water use was also small and when the water deficit was larger, water use was also larger. For example, between October 1967 and September 1968, household water consumption was the greatest in the month of August, coinciding with the greatest monthly water deficit for that time period.

In order to determine how a family's socio-economic characteristics are related to water use patterns, households were classified into different socio-economic classes. It was found that as the family income or value of the home (market or assessed value) increased, the average annual

water use also increased. For example, while only approximately 5 percent of the families with annual incomes less than $10,000 used over 14,000 gallons of water per year, 60 percent of the families with incomes over $20,000 used this amount of water.

Seasonal variation in water use was also found to increase with the socio-economic level of the household. This increased variation was due to the fact that higher income families use more water during the summer months for lawn sprinkling than lower income families. Moreover, the seasonal peaking increased at a faster rate as the value of the home or income increased than the average water use. The ratio of average monthly consumption to average maximum monthly consumption increased from approximately 1:2 for the lowest wealth classes of each of the socio-economic characteristics studied to a ratio of 1:4 for the highest wealth classes.

A large amount of variation of water use was found for metered households within the same socio-economic class. For example, while the average water use of families making less than $5,000 per year was 7,200 gallons in May, some households in the same wealth class used approximately 17,000 gallons of water for that month. The average consumption in May for families making over $20,000 was 26,200 gallons, but some households in the same income class used as much as 108,000 gallons of water for that same month. Since metered customers in the same wealth class had such a large variation in water use, there is no reason why flat rate homes in the same socio-

economic class (and hence pay the same rate for their water) should not demonstrate similar attributes.

Predictive Models for Residential Water Use

Multiple regression and correlation analysis were used to analyze the present method of flat rate pricing in Calgary and to develop alternative ways of estimating household water use. The present method of assessing flat rates in Calgary was found to be unsatisfactory, primarily because this method was lacking some of the factors most closely associated with water use. Of the variables most closely associated with water use (value of the home, lot size and number of persons in the home) only one variable, lawn area, is used in the present assessment rates.[1] Besides lawn area, the other variables that appeared to be the most important variables were washbasins/sinks, number of rooms and toilets. These four variables had an explained variation of .677 out of the explained variation of .679 when eight of the thirteen variables used in assessing flat rates were entered into a linear regression model. Two of the variables, washbasins/sinks and lawn area, were significant at the 5 percent probability level. When the calculated regression coefficients for the assessment items were compared to the assessment rate there seemed to be very little relationship between the rate charged and the water consumption for that item. For example,

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[1]Lawn area and lot size were found to be close substitutes for each other. Lot size, however, is the more preferable variable since it did produce slightly better statistical results than lawn area and is also more easily available.

washbasins/sinks had a regression coefficient of 8,440 gallons of water and an assessment of $2.31, while lawn area had a regression coefficient of 7,044 gallons of water per 1,000 square feet and an assessment of $0.63 per 1,000 square feet.

In order to present alternative models, linear and non-linear equations using various combinations of variables were computed. The results of these models showed that estimates as statistically as good as the present model may be achieved from using other data. Equations on estimating annual residential water consumption using only secondary data (i.e. public records) and other easily available data (i.e. number of rooms and number of persons per household) had an explained variation of .707 with all the variables significant at the 1 percent probability level in non-linear form; an explained variation of .699 and all variables significant at the 1 percent level was obtained for the linear form. All algebraic signs for the calculated regression coefficients were as expected.

Employing only secondary data (e.g. lot size and assessed value of the home) a linear equation with an explained variation of .602 and a non-linear equation with an explained variation of .642 were obtained. Variables in both models were significant at the 1 percent probability level.

Seasonal estimation models were also determined in order to find out which variables are important at what time of the year. It turned out that lawn area (or lot size) was an important predictive variable during the winter season as

well as the summer. The importance of lawn area during the winter may be due to the existing multicollinearity between lawn area and other variables. Number of persons and assessed value of the home were also found to be important predictors of water use during both seasons.

When the substitutibility of value of the home for family income was tested, it proved that home value gave a better estimation of residential water use than family income. It also turned out that assessed value of the home obtained from public records gave as good an estimate of water use as the market value of the home as estimated by the occupant of the home.

Because lot size is more easily obtained, substitutibility of these variables was examined. It turned out that when lot size was used as a proxy for lawn area, the statistical estimation of water use was not altered significantly. That is, lawn area and lot size proved to be good substitutes for each other.

The income elasticity of water consumption, computed at the mean, was determined to be +0.207. That is, a 10 percent increase in family income would result in an increase of water use of 2 percent. This elasticity means that the water system will not have to increase its capacity fully proportionately to increases in income of its users.

Implications

Policy Implications

From the findings in this study two important policy implications may be drawn. The first is that the City of Calgary should have metering for all residential households. Flat rate pricing is undesirable for several reasons: flat rate customers have no reason to restrict their water use; a great deal of water is wasted by these customers. This excessive waste has the effect of increasing the costs of the entire water system, which results in higher prices of water to all other users. In addition, flat rate pricing produces inequities within similar socio-economic classes of customers. No matter how narrow the definition of a socio-economic class is, there is nothing to prevent one user in the class to consume more water than another user in the same class.

The other policy implication is that if the present flat rate pricing is continued, there should be some consideration to alternative methods of assessment which appear to have some advantages over the present method. The use of secondary or public data along with other easily available data give as good an estimation of residential water use as the present method with less work. The inclusion of assessed value of the home and number of persons in the home into the assessment scheme is recommended to improve the equity of the flat rate pricing system. The assessed rates for the items used in the assessment schedule should also be carefully reviewed to insure that the rates are as fair as possible.

Planning Implications

One of the implications for future planning which may be drawn from the results of this study is that the water system can plan to deliver the most water and find the greatest contributors to peaks in the higher socio-economic areas of the city. The income elasticity has shown, however, that while the city can expect to deliver more water to a family as income increases, the increased rate of water use is less than proportional to the increase in income.

Future Research

The finding that non-response bias is obtained from the use of mail questionnaires presents an important consideration for future surveys. Because of the non-response bias which a mail questionnaire lends itself to, consideration should be given to using personal interviews as a follow-up to the mail questionnaire. If only a mail questionnaire is used to obtain survey data, then any conclusions drawn from that data must be made with the understanding that biased sample returns may have formed the basis for these conclusions.

While this study has examined various factors affecting residential water use, one of the major factors, price, has not been examined. Further research should be undertaken to study the effect of price on water consumption. At present a study is being undertaken by the Department of Agricultural Economics and Rural Sociology, University of Alberta[1] to determine the effect of price on consumption. This study is

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[1]This study is being financed by the Department of Energy, Mines and Resources, Ottawa.

being done by examining numerous cities and towns in Alberta, including Calgary, so as to obtain different price structures and the consumer reaction to these prices (i.e. demand curve). The results of this provincial study should prove beneficial in promoting better water pricing policies.

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APPENDICES

APPENDIX A

CALCULATION OF POTENTIAL EVAPOTRANSPIRATION

Water loss from the earth by transpiration from vegetation and by direct evaporation is an important part of the water balance problem. Recent studies have pointed out that drought cannot be adequately defined in terms of deficiency and variability of precipitation alone since these definitions do not take into account the amount of water needed during the growing season.[1] Drought may be better defined in terms of the amount that the available water supply (i.e. precipitation and moisture storage) is exceeded by the amount needed for evaporation and transpiration. The amount of water needed for evaporation and transpiration is measured in terms of the amount of water that will be lost from a surface completely covered with vegetation if there is sufficient water in the soil at all times for the use of this vegetation. This water loss is called potential evapotranspiration.

There are numerous methods available to calculate evapotranspiration, none of which are free from assumptions, arbitrary constants, or technical difficulties (e.g. data measurement). The Thornthwaite method of 1948, which is based on an empirical relationship between potential evapotranspiration and mean air temperature, was selected for use in this study. This method was selected because it can be employed for any station having monthly temperature and precipitation

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[1]For example, A. Laycock, Water Deficiency and Surplus Patterns in the Prairie Provinces, Report No. 13 (Regina, Sask: Hydrological Division, Prairie Farm Rehabilitation Administration, March, 1967).

data, necessary data is easily available at no additional cost,[1] the method has been shown to give similar results as other methods including the more complex Thornthwaite procedures of 1955 and 1957.[2] While this method has been widely accepted primarily on the simplicity of its data requirements, the major criticisms have been on its basic assumption that a high correlation exists between mean temperature and other important parameters such as wind or radiation. These limitations may be of importance in some cases, but generally they are unimportant.

Thornthwaite's basic formula for computing monthly potential evapotranspiration is[3]:

$$e = 1.6\ (10\ T/I)^{a}$$

Where: e = monthly potential evapotranspiration (cm.)

T = monthly mean temperature (Centigrade)

I = a heat index which is a constant for a given location and is the sum of twelve monthly index values i, where i is a function of the monthly normal temperatures $(i = t/5)^{1.514}$.

a = an empirically determined exponent which is a function of I, $a = 6.75 \times 10^{-3} I^{3} - 7.71 \times 10^{-5} I^{2} + 1.79 \times 10^{-2}\ I + o.49$

The resulting value e may then be adjusted for day and month length by consulting available tables for the coefficient to

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[1]Data was obtained from the Canada Department of Transport, Meteorological Branch, Monthly Record, Meteorological Observations in Canada (Ottawa: Queen's Printer, Oct. 1967-Sept. 1968).

[2]A. Laycock, Op. cit., p. 1, Appendix A.

[3]C.W. Thornthwaite, "An Approach Toward a Rational Classification of Climate," Geographical Review, XXXVIII (1948). 55-94.

multiply the unadjusted potential evapotranspiration by for that particular stations' latitude and the month of the year.[1]

The water balance was then calculated for Calgary by finding the difference between potential evapotranspiration and the amount of precipitation for each month during the summer.[2] Winter calculations of evapotranspiration were not done since the mean temperature is below 32 degrees Fahrenheit for these months, hence there is no evapotranspiration or need to water lawns to replenish lost moisture.

APPENDIX B

MISCELLANEOUS TABLES AND FIGURES

Table 1

SCHEDULE OF WATER RATES
CITY OF CALGARY, 1967-1968

METERED RATES

METER SCHEDULE

First	5,000	62¢ per 1,000 Gals.
Next	5,000	56¢ per 1,000 Gals.
Next	20,000	50¢ per 1,000 Gals.
Next	30,000	41¢ per 1,000 Gals.
Next	90,000	28¢ per 1,000 Gals.
Next	350,000	25¢ per 1,000 Gals.
All over	500,000	21¢ per 1,000 Gals.

SPECIAL GARDEN RATE, MAY TO SEPTEMBER (INCLUSIVE) ONLY

First	5,000	62¢ per 1,000 Gals.
Next	5,000	28¢ per 1,000 Gals.
All over	10,000	25¢ per 1,000 Gals.

MINIMUM CHARGE ON METERS

1/2	inch service per month	$3.10
3/4	inch service per month	$3.43
1	inch service per month	$4.06
1 1/2	inch service per month	$7.70
2	inch service per month	$10.78
3	inch service per month	$15.40
4	inch service per month	$23.10
6	inch service per month	$38.50

Table 1 (continued)

ASSESSED FLAT RATES

DOMESTIC RATE - SINGLE FAMILY

*No. of Rooms		Rate per Annum	
3	21.56	*Dishwashers, each	$2.31
4	23.10	*Basin in private dwelling, each	$2.31
5	24.64	*Water Closet, each	$4.62
6	26.18	*Baths, each	$4.97
7	27.30	*Sinks, each	$2.31
8	28.49	*Tap or additional fixtures	$1.12
9	29.61	*Lawns or Garden per 1,000 sq. ft. of lot	.63
10	30.80	Automobiles, each	$2.31
11	31.92	Laundry Tubs, per set	$2.31
12	33.11	Public Standpipe or Tap, each consumer	$15.40
13	34.30	Minimum Flat Rate, per annum	$24.64
14	35.42	Private Hydrant	$23.10
15	36.54		
Each additional Room	$1.19		

*Data for these items was obtained for the households in this study.

Table 2

SUB-SAMPLE MEANS, METERED CUSTOMERS, CITY OF CALGARY

Item	Mail Response Complete	Mail Response Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtain-able Response	Response Refused
No. of observations	130	48[a]	17	27[b]	41[c]	29[c]
			FAMILY CHARACTERISTICS			
No. of Persons						
mean	3.71	3.37	3.29	4.15	3.56	3.61
S.D.	0.15	0.19	0.29	0.42	0.55	0.65
Income ($)						
mean	11,623	10,963	7,382	10,007	10,081	10,943
S.D.	1,022	3,320	678	2,580	4,093	4,869
			HOUSEHOLD CHARACTERISTICS			
Rooms						
mean	6.89	6.52	6.06	6.07	6.57	5.81
S.D.	0.17	0.23	0.41	0.30	0.89	1.06
Washing machine						
mean	0.97	1.02	1.00	0.96	0.96	0.97
S.D.	0.02	0.02	0.00	0.04	0.11	0.13

Table 2 (continued)

Item	Mail Response Complete	Mail Response Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtain-able Response	Response Refused
No. of observations	130	48[a]	17	27[b]	41[c]	29[c]
Auto. gar. disp.						
mean	0.16	0.23	0.18	0.18	0.16	0.17
S.D.	0.03	0.06	0.09	0.08	0.26	0.31
Dishwasher						
mean	0.17	0.15	0.12	0.15	0.18	0.13
S.D.	0.03	0.05	0.08	0.07	0.26	0.30
Tubs/Showers						
mean	1.47	1.60	1.65	1.67	1.44	1.50
S.D.	0.05	0.11	0.21	0.13	0.27	0.34
Basins/Sinks						
mean	3.11	3.17	2.53	2.74	2.94	2.98
S.D.	0.10	0.17	0.12	0.19	0.43	0.51
Toilets						
mean	1.72	1.77	1.59	1.56	1.66	1.68
S.D.	0.07	0.09	0.15	0.13	0.26	0.31

continued

Table 2 (continued)

Item	Mail Response Complete	Mail Response Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtain-able Response	Response Refused
No. of observations	130	48[a]	17	27[b]	41[c]	29[c]
Other taps						
mean	2.12	1.56	1.29	1.85	2.04	2.03
S.D.	0.10	0.15	0.22	0.22	0.37	0.44
Market value ($)						
mean	21,988	23,221	18,882	22,583	19,960	21,284
S.D.	1,122	2,736	1,801	3,491	3,512	4,177
Land Asses. ($)						
mean	2,120	2,084	1,829	2,193	1,918	2,079
S.D.	109	147	141	151	155	178
Bldg. Asses.						
mean	5,136	4,931	4,008	5,235	5,368	5,009
S.D.	272	372	406	518	450	388
Lot size (sq. ft.)						
mean	6,285	6,309	5,505	6,358	5,715	6,442
S.D.	212	290	321	303	319	509
Bldg. area (sq. ft.)						
mean	1,299	1,232	1,396	1,332	1,225	1,229
S.D.	46	62	134	81	72	97

continued

Table 2 (continued)

Item		Mail Response Complete	Mail Response Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtainable Response	Response Refused
No. of observations		130	48[a]	17	27[b]	41[c]	29[c]
				WATER CONSUMPTION [GALLONS]			
Oct. 1967							
	mean	6,295	4,583	4,471	4,815	5,650	4,893
	S.D.	641	467	594	673	1,012	413
Nov. 1967							
	mean	4,344	5,313	6,294	3,926	5,025	4,821
	S.D.	207	967	2,259	388	800	391
Dec. 1967							
	mean	4,805	5,188	4,294	3,704	5,050	5,000
	S.D.	323	1,348	512	461	517	642
Jan. 1968							
	mean	5,760	4,438	4,471	6,148	5,902	4,607
	S.D.	413	386	536	1,309	784	4,985
Feb. 1968							
	mean	5,023	5,354	5,741	4,667	4,564	4,929
	S.D.	261	759	748	533	784	592

continued

Table 2 (continued)

Item	Mail Response Complete	Mail Response Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtainable Response	Response Refused
No. of observations	130	48[a]	17	27[b]	41[c]	29[c]
March 1968						
mean	5,359	5,250	6,118	5,296	6,897	4,929
S.D.	306	425	731	735	1,123	381
April 1968						
mean	7,504	6,313	5,412	6,481	6,351	7,464
S.D.	732	506	600	656	658	1,122
Winter Total						
mean	38,599	36,438	36,529	35,037	37,878	35,379
S.D.	2,929	2,502	3,409	3,566	3,729	2,912
May 1968						
mean	9,612	8,229	8,765	7,667	7,405	8,357
S.D.	921	892	1,041	1,142	649	1,716
June 1968						
mean	8,574	8,042	7,882	8,333	8,892	10,143
S.D.	485	908	1,041	1,120	1,053	1,711

continued

Table 2 (continued)

Item		Mail Response Complete	Mail Response Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtain-able Response	Response Refused
No. of observations		130	48[a]	17	27[b]	41[c]	29[c]
July 1968							
	mean	10,783	10,479	7,647	9,926	9,889	10,929
	S.D.	647	930	822	1,455	1,170	1,643
Aug. 1968							
	mean	11,140	9,917	7,059	8,481	10,194	9,607
	S.D.	652	1,091	769	1,036	1,198	1,332
Sept. 1968							
	mean	8,727	6,708	9,063	8,963	7,514	8,643
	S.D.	755	541	2,561	1,830	1,204	1,150
Summer Total							
	mean	47,748	43,375	39,882	43,370	42,946	47,679
	S.D.	2,334	2,817	2,997	4,787	4,752	7,091
Annual Total							
	mean	86,347	79,813	76,412	78,407	76,634	81,414
	S.D.	3,491	4.665	4.831	7,959	7,438	9,405

continued

Table 2 (continued)

Item		Mail Response Complete	Mail Response Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtain-able Response	Response Refused
No. of observations		130	48[a]	17	27[b]	41[c]	29[c]
				AMOUNT PAID FOR WATER ($)			
Oct. 1967							
	mean	4.22	3.69	3.62	3.67	4.17	3.76
	S.D.	.28	.19	.15	.28	.45	.22
Nov. 1967							
	mean	3.49	4.34	4.33	3.34	3.89	3.61
	S.D.	.09	.60	1.03	.12	.36	.19
Dec. 1967							
	mean	3.82	4.03	3.56	3.42	3.80	3.80
	S.D.	.17	.56	.21	.12	.20	.30
Jan. 1968							
	mean	4.13	3.61	3.52	4.50	4.24	3.67
	S.D.	.19	.14	.15	.60	.41	.20
Feb. 1968							
	mean	3.63	3.86	3.85	3.62	3.54	3.69
	S.D.	.11	.34	.31	.20	.20	.27

continued

Table 2 (continued)

Item	Mail Response Complete	Mail Response Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtain-able Response	Response Refused
No. of observations	130	48[a]	17	27[b]	41[c]	29[c]
March 1968						
mean	3.89	3.81	4.08	3.87	4.58	4.72
S.D.	.16	.17	.32	.28	.52	1.22
April 1968						
mean	4.16	3.70	3.49	4.80	4.00	3.91
S.D.	.26	.11	.23	.60	.37	.27
Winter Total						
mean	27.20	27.05	26.46	27.22	27.15	27.02
S.D.	.81	.98	1.29	1.27	1.54	2.32
May 1968						
mean	4.40	4.42	4.35	3.92	3.89	4.15
S.D.	.23	.51	.32	.28	.15	.43
June 1968						
mean	4.16	4.16	3.99	4.00	4.24	4.56
S.D.	.13	.23	.23	.32	.26	.42

continued

Table 2 (continued)

Item		Mail Response Complete	Mail Response Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtainable Response	Response Refused
No. of observations		130	48[a]	17	27[b]	41[c]	29[c]
July 1968	mean	4.90	4.58	3.91	4.61	4.56	4.77
	S.D.	.22	.24	.20	.36	.29	.43
Aug. 1968	mean	4.98	4.65	3.92	4.34	4.54	4.39
	S.D.	.21	.28	.25	.29	.30	3.75
Sept. 1968	mean	4.41	3.93	4.43	4.69	4.07	4.23
	S.D.	.20	.18	.62	.47	.40	.32
Summer Total	mean	22.85	21.73	20.59	21.56	20.94	22.11
	S.D.	.63	.85	.76	1.11	1.28	1.81
Annual Total	mean	49.88	48.78	47.06	48.79	46.05	48.37
	S.D.	1.29	1.48	1.50	2.13	2.52	1.81

continued

Table 2 (continued)

FOOTNOTES

[a]Income and Market Value are weighted averages between actual obyained data and estimated data for the group; all other data is actual obtained data. There were two actual observations for Income and twenty-eight for Market Value.

[b]Same as above except that there were six actual Income and nine actual Market Value observations.

[c]All figures up to and including Market Value were estimated by employing regression estimates. See M. Hanson, *et al*., *Sample Survey Methods and Theory*, Vol. I (New York: John Wiley & Sons, 1953), *p. 457*.

[d]Standard deviations of the population estimates were calculated according to above p. 25.

Table 3

SUB-SAMPLE MEANS, FLAT RATE CUSTOMERS, CITY OF CALGARY

Item	Mail Responses Complete	Mail Responses Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtainable Response	Refused Response
No. of observations	248	106[a]	17	31[b]	92	29
FAMILY CHARACTERISTICS						
No. of Persons						
mean	4.08	3.77	4.06	3.84	4.06	3.99
S.D.	0.10	0.19	0.31	0.32	1.06	1.91
Income ($)						
mean	10,302	9,924	9,594	8,493	9,174	9,829
S.D.	424	3,751	1,534	4,955	3,923	7,010
HOUSEHOLD CHARACTERISTICS						
Rooms						
mean	6.58	5.74	6.59	5.90	6.85	5.87
S.D.	0.11	0.18	0.48	0.32	1.11	1.98
Washing Machines						
mean	0.98	0.97	1.00	0.97	0.98	0.98
S.D.	0.01	0.02	0.00	0.07	0.12	0.21

continued

Table 3 (continued)

Item	Mail Responses Complete	Mail Responses Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtain-able Response	Refused Response
No. of observations	248	106[a]	17	31[b]	92	29
Auto. Garbage Disp.						
mean	0.17	0.10	0.18	0.10	0.11	0.12
S.D.	0.002	0.03	0.09	0.05	0.50	0.28
Dishwasher						
mean	0.18	0.15	0.23	0.06	0.13	0.11
S.D.	0.02	0.03	0.11	0.04	0.29	0.51
Tubs/Showers						
mean	1.33	1.32	1.29	1.39	1.30	1.32
S.D.	0.04	0.06	0.11	0.11	0.37	0.66
Basins/Sinks						
mean	2.67	2.54	2.88	2.55	2.58	2.49
S.D.	0.06	0.08	0.22	0.16	0.58	1.04
Toilets						
mean	1.55	1.47	1.59	1.48	1.65	1.42
S.D.	0.05	0.06	0.15	0.13	0.38	0.68

continued

Table 3 (continued)

Item	Mail Responses Complete	Mail Responses Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtain-able Response	Refused Response
No. of observations	248	106[a]	17	31[b]	92	29
Other Taps						
mean	1.77	1.39	2.00	1.32	1.08	1.45
S.D.	0.07	0.08	0.39	0.08	1.80	3.22
Market Value ($)						
mean	20464	18250	22294	20670	18335	19278
S.D.	629	2381	3131	5473	4055	7247
Land Asses. ($)						
mean	2048	1986	2311	2173	1823	1895
S.D.	68	132	410	292	68	118
Bldg. Asses. ($)						
mean	4716	4288	4631	4703	4002	4098
S.D.	120	265	525	336	258	499
Lot Size (sq. ft.)						
mean	6353	5968	6873	6174	5980	6430
S.D.	157	213	704	371	164	938

continued

Table 3 (continued)

Item	Mail Responses Complete	Mail Responses Incomplete	Personal Interview Complete Response	Personal Interview Incomplete Response	Unobtainable Response	Refused Response
No. of observations	248	106[a]	17	31[b]	92	29
Bldg. Area (sq. ft.)						
mean	1230	1196	1257	1367	1148	1182
S.D.	27	38	124	143	40	70
AMOUNT PAID FOR WATER ($)						
Winter (Oct. 1967 - April 1968)						
mean	31.13	30.74	31.40	32.57	30.83	29.75
S.D.	.32	.55	1.40	1.06	.55	.96
Summer (May 1968 - Sept. 1968)						
mean	22.23	21.96	22.42	23.26	22.02	21.25
S.D.	.32	.39	1.00	.76	.39	0.69
Annual (Oct. 1967 - Sept. 1968)						
mean	53.36	52.70	53.83	55.83	52.85	51.00
S.D.	.55	.94	2.40	1.82	.95	1.65

continued

Table 3 (continued)

FOOTNOTES

[a]Except for market value which was 49 and income which was 5.

[b]Except for market value which was 10 and income which was 9.

[c]Standard deviation of the population estimate calculated according to M. Hanson, _et al._, _Op. cit._, p. 25.

Table 4

CUSTOMER WATER USE IN THE U.S.
(UTILITIES SERVING 10,000 OR MORE PEOPLE)

Customer Class	No. of Cities	Annual Use Per Service 1,000 Imperial Gallons		
		Min.	Max.	Mean
PUBLICLY OWNED UTILITIES				
Residential	272	22	311	77
Commercial	178	36	5,412	458
Industrial	169	19	629,506	18,319
PRIVATELY OWNED UTILITIES				
Residential	66	27	199	55
Commercial	50	59	999	275
Industrial	51	59	45,797	7,494

Source: Seidel and Cleasby, _Op. cit_., 1512.

Table 5

SUMMARY OF JOHNS HOPKINS RESIDENTIAL WATER USE STUDY

Type of Study Area	Number of Study Areas	Mean of Annual Uses	Mean of Maximum Daily Uses	Mean of Peak Hourly Uses
		Imperial Gallons Per Day Per Dwelling Unit		
Residential Areas:				
Metered public water and public sewers,				
West	10	381	815	2065
East	13	258	654	1524
Metered public water and septic tanks	5	204	604	1528
Flat rate public water and public sewers	8	576	1957	4305
Apartment areas	5	159	306	799
	--	---	---	---
All study areas	41	331	916	2140

Source: Linaweaver, et al., Op. cit., 269.

Table 6

RATE OF WATER USE AND NUMBER OF PERSONS, METERED CUSTOMERS, CITY OF CALGARY[a]
OCTOBER 1967 - SEPTEMBER 1968
[TOTAL SAMPLE = 100 PERCENT]

[Imperial Gallons]	All Number Classes	Number of Persons Per House						
		1	2	3	4	5	6	7 or More
All Use Classes	100.0	4.1	25.9	19.0	23.1	15.0	6.8	6.2
Up to 5,499[b]	25.9	2.7	12.2	6.1	3.4	0.0	1.4	0.0
5,500 to 8,499	47.6	0.0	8.8	8.8	15.6	9.5	3.4	1.4
8,500 to 11,499	17.7	1.4	2.7	2.7	3.4	3.4	1.4	2.7
11,500 to 14,499	3.4	0.0	0.0	0.0	0.7	2.0	0.0	0.7
14,500 and Over	5.4	0.0	2.0	1.4	0.0	0.0	0.7	1.4

[a] $N = 147$, $Chi^2 = 66.28$, d.f. = 32, $p > 99$.

[b] Total amount of water allowed under monthly minimum charge.

Table 7

RATE OF WATER USE AND GROSS FAMILY INCOME, METERED CUSTOMERS, CITY OF CALGARY[a]
OCTOBER 1967 - SEPTEMBER 1968
[TOTAL SAMPLE = 100 PERCENT]

Water Use Per Month [Imperial Gallons]	All Value Classes	Gross Family Income [$] Up to 4,999	5,000 to 9,999	10,000 to 14,999	15,000 to 19,999	20,000 and over
All Use Classes	100.0	11.6	44.2	28.6	8.8	6.8
Up to 5,499[b]	25.9	5.4	13.6	6.8	0.0	0.0
5,500 to 8,499	47.6	4.1	21.1	15.0	6.1	1.4
8,500 to 11,499	17.7	1.4	7.5	5.4	2.0	1.4
11,500 to 14,499	3.4	0.0	1.4	0.7	0.7	0.7
14,500 and Over	5.4	0.7	0.7	0.7	0.0	3.4

[a] N = 147, $Chi^2 = 56.29$, d.f. = 16, $p > 99$.

[b] Total amount of water allowed under monthly minimum charge.

Table 8

RATE OF WATER USE AND MARKET VALUE OF HOME, METERED CUSTOMERS, CITY OF CALGARY[a]
OCTOBER 1967 - SEPTEMBER 1968
[TOTAL SAMPLE = 100 PERCENT]

Water Use Per Month [Imperial Gallons]	All Value Classes	Market Value of Home [$]				
		Up to 10,000	11,000 to 20,000	21,000 to 30,000	31,000 to 40,000	41,000 and Over
All Use Classes	100.0	4.1	61.9	25.2	5.4	3.4
Up to 5,499[b]	25.9	2.0	20.4	3.4	0.0	0.0
5,500 to 8,499	47.6	2.0	29.3	14.3	2.0	0.0
8,500 to 11,499	17.7	0.0	10.2	4.8	2.7	0.0
11,500 to 14,499	3.4	0.0	1.4	1.4	0.7	0.0
14,500 and Over	5.4	0.0	0.7	1.4	0.0	3.4

[a] $N = 147$, $Chi^2 = 107.87$, d.f. = 16, $p > 99$.

[b] Total amount of water allowed under monthly minimum charge.

Table 9

RATE OF WATER USE AND TOTAL ASSESSMENT OF HOME, METERED CUSTOMERS, CITY OF CALGARY[a]
OCTOBER 1967 - SEPTEMBER 1968
[TOTAL SAMPLE = 100 PERCENT]

Water Use Per Month [Imperial Gallons]	All Assessment Classes	Total Assessed Value of Home [$]				
		Up to 5,000	5,001 to 8,000	8,001 to 11,000	11,001 to 14,000	14,001 and Over
All Use Classes	100.0	19.7	59.9	13.6	2.7	4.1
Up to 5,499[b]	25.9	10.2	12.9	2.0	0.0	0.7
5,500 to 8,499	47.6	7.5	31.3	8.8	0.0	0.0
8,500 to 11,499	17.7	2.0	12.9	1.4	1.4	0.0
11,500 to 14,499	3.4	0.0	2.0	0.0	0.7	0.7
14,500 and Over	5.4	0.0	0.7	1.4	0.7	2.7

[a] $N = 147$, $Chi^2 = 82.74$, d.f. = 16, $p > 99$.

[b] Total amount of water allowed under monthly minimum charge.

Table 10

RATE OF WATER USE AND NUMBER OF ROOMS
METERED CUSTOMERS, CITY OF CALGARY[a]
OCTOBER 1967 - SEPTEMBER 1968
[TOTAL SAMPLE = 100 PERCENT]

Water Use Per Month [Imperial Gallons]	All Room Classes	Number of Rooms Per Household					
		3	4	5	6	7	8 and Over
All Use Classes	100.0	0.7	7.5	18.4	24.5	18.4	30.6
Up to 5,499[b]	25.9	0.7	3.4	7.5	7.5	4.8	2.1
5,500 to 8,499	47.6	0.0	2.7	9.5	13.6	6.8	15.0
8,500 to 11,499	17.7	0.0	1.4	1.4	2.7	4.1	9.2
11,500 to 14,499	3.4	0.0	0.0	0.0	0.7	0.7	2.1
14,500 and Over	5.4	0.0	0.0	0.0	0.0	2.0	3.5

[a] $N = 147$, $Chi^2 = 46.01$, d.f. = 32, $p > 99$.

[b] Total amount of water allowed under monthly minimum charge.

Table 11

RATE OF WATER USE AND LAWN AREA,
METERED CUSTOMERS, CITY OF CALGARY[a]
OCTOBER 1967 - SEPTEMBER 1968
[TOTAL SAMPLE = 100 PERCENT]

Water Use Per Month [Imperial Gallons]	All Lawn Classes	Lawn Area [sq. ft.] Up to 3,000	3,001 to 5,000	5,001 to 7,000	7,001 to 9,000	9,000 and Over
All Use Classes	100.0	10.2	56.5	24.5	5.4	3.4
Up to 5,499[b]	25.9	7.5	10.9	6.8	0.7	0.0
5,500 to 8,499	47.6	2.7	33.3	10.2	0.7	0.7
8,500 to 11,499	17.7	0.0	9.5	5.4	2.7	0.0
11,500 to 14,499	3.4	0.0	1.4	1.4	0.0	0.7
14,500 and Over	5.4	0.0	1.4	0.7	1.4	2.0

[a] $N = 147$, $Chi^2 = 73.09$, d.f. = 16. $p > 99$.

[b] Total amount of water allowed under monthly minimum charge.

Table 12

RATE OF WATER USE AND HOUSEHOLD APPLIANCES AND FIXTURES
METERED CUSTOMERS, CITY OF CALGARY[a]
OCTOBER 1967 - SEPTEMBER 1968
[TOTAL SAMPLE = 100 PERCENT]

Number of Appliances or Fixtures in Household		Water Use Per Month [Imperial Gallons]				
		Up to 5,499[b]	5,500 to 8,499	8,500 to 11,499	11,500 to 14,499	14,500 and Over
Washing Machine	100.0	25.9	47.6	17.7	3.4	5.4
0	4.8	2.7	1.4	0.7	0.0	0.0
1	93.2	23.1	45.6	15.6	3.4	5.4
2	2.0	0.0	0.7	1.4	0.0	0.0
	[a]$N = 147$, $Chi^2 = 9.32$, d.f. = 8, $p > 50$					
Auto. Gar. Disp.						
0	83.7	23.8	40.1	13.6	3.4	2.7
1	16.3	2.0	7.5	4.1	0.0	2.7
	[a]$N = 147$, $Chi^2 = 10.48$, d.f. = 4, $p > 95$					
Dishwasher						
0	83.7	25.2	41.5	12.9	2.0	2.0
1	16.3	0.7	6.1	4.8	1.4	3.4
	[a]$N = 147$, $Chi^2 = 22.51$, d.f. = 4, $p > 99$					

continued

Table 12 (continued)

Number of Appliances or Fixtures in Household		Water Use Per Month [Imperial Gallons]				
		Up to 5,499[b]	5,500 to 8,499	8,500 to 11,499	11,500 to 14,499	14,500 and Over
Tubs/Showers						
0	0.0	0.0	0.0	0.0	0.0	0.0
1	59.2	18.4	32.7	6.8	0.7	0.7
2	34.7	7.5	12.9	9.5	2.7	2.0
3	4.1	0.0	1.4	1.4	0.0	1.4
4	2.0	0.0	0.7	0.0	0.0	1.4
	[a] $N = 147$, $Chi^2 = 48.93$, d.f. $= 12$, $p > 99$					
Basins/Sinks						
0	0.0	0.0	0.0	0.0	0.0	0.0
1	3.4	1.4	1.4	0.7	0.0	0.0
2	34.7	12.9	17.0	4.1	0.0	0.7
3	28.6	9.5	15.0	2.7	0.7	0.7
4	24.5	2.0	12.2	6.8	2.0	1.4
5	6.1	0.0	2.0	3.4	0.7	0.0
6	2.0	0.0	0.0	0.0	0.0	2.0
7	0.7	0.0	0.0	0.0	0.0	0.7
	[a] $N = 147$, $Chi^2 = 101.45$, d.f. $= 24$, $p > 99$					
Toilets						
0	0.0	0.0	0.0	0.0	0.0	0.0
1	43.5	15.6	22.4	5.4	0.0	0.0

continued

Table 12 (continued)

Number of Appliances or Fixtures in Household		Water Use Per Month [Imperial Gallons] Up to 5,499[b]	5,500 to 8,499	8,500 to 11,499	11,500 to 14,499	14,500 and Over
2	44.9	10.2	22.4	8.8	1.4	2.0
3	9.5	0.0	2.7	3.4	2.0	1.4
4	1.4	0.0	0.0	0.0	0.0	1.4
5	0.7	0.0	0.0	0.0	0.0	0.7

[a]N = 147, Chi^2 = 84.73, d.f. = 16, p < 99

Other Taps						
0	4.8	1.4	2.7	0.0	0.0	0.7
1	33.3	9.5	17.0	5.4	1.4	0.0
2	29.3	4.8	15.6	8.2	0.0	0.7
3	23.8	8.2	8.8	2.7	1.4	2.7
4	6.1	1.4	2.7	0.0	0.7	1.4
5	1.4	0.7	0.0	0.7	0.0	0.0
6	1.4	0.0	0.7	0.7	0.0	0.0

[a]N = 147, Chi^2 = 30.21, d.f. = 24, p < 50

[b]Total amount of water allowed under monthly minimum charge.

Figure 1

RESIDENTIAL WATER USE QUESTIONNAIRE

RESIDENTIAL WATER USE STUDY - A. SINGLE-DWELLING UNITS

1. Number of persons who lived in this house January, 1968?
2. Number of rooms* in this house?
3. Number of water using appliances and installations?

Washing Machine	Bath tubs and shower cabinets
Autom. garbage disposal	Wash basins and sinks
Dishwasher	Toilets
Swimming pool	Additional water taps

4. Approximate size of lawn and garden? ______ feet X ______ feet OR ______ square feet
5. Current market value of your home (the price a similiar home would sell for today)? $ ____,000
6. Approximate gross family income during last 12 months (income before income taxes and other deductions; include income from all other sources, and of all persons living in this house)? $ ____,000

Please complete form and return in business reply envelope to:

DEPARTMENT OF AGRICULTURAL ECONOMICS
The University of Alberta, Edmonton, Alberta.

Figure 2

ADVERTISEMENT USED IN RESIDENTIAL WATER USE STUDY